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Bates et al.

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(54) **SYSTEMS AND METHODS FOR OPTICAL MEDICAL INSTRUMENT PATIENT MEASUREMENTS**

(71) Applicants: **James Stewart Bates**, Paradise Valley, AZ (US); **Kristopher Perry**, Phoenix, AZ (US); **Chaitanya Prakash Potaraju**, Tempe, AZ (US); **Pranav Bhatkal**, Tempe, AZ (US); **Aditya Shirvalkar**, Tempe, AZ (US); **Tristan Royal**, Phoenix, AZ (US)

(72) Inventors: **James Stewart Bates**, Paradise Valley, AZ (US); **Kristopher Perry**, Phoenix, AZ (US); **Chaitanya Prakash Potaraju**, Tempe, AZ (US); **Pranav Bhatkal**, Tempe, AZ (US); **Aditya Shirvalkar**, Tempe, AZ (US); **Tristan Royal**, Phoenix, AZ (US)

(73) Assignee: **AdviNow, Inc.**, Paradise Valley, CA (US)

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A61B 1/00 (2006.01)
A61B 5/00 (2006.01)
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CPC ***A61B 1/00147*** (2013.01); ***A61B 1/227*** (2013.01); ***A61B 1/24*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC A61B 1/00; A61B 5/1128; A61B 5/1114; A61B 1/00059; A61B 5/0205;
(Continued)

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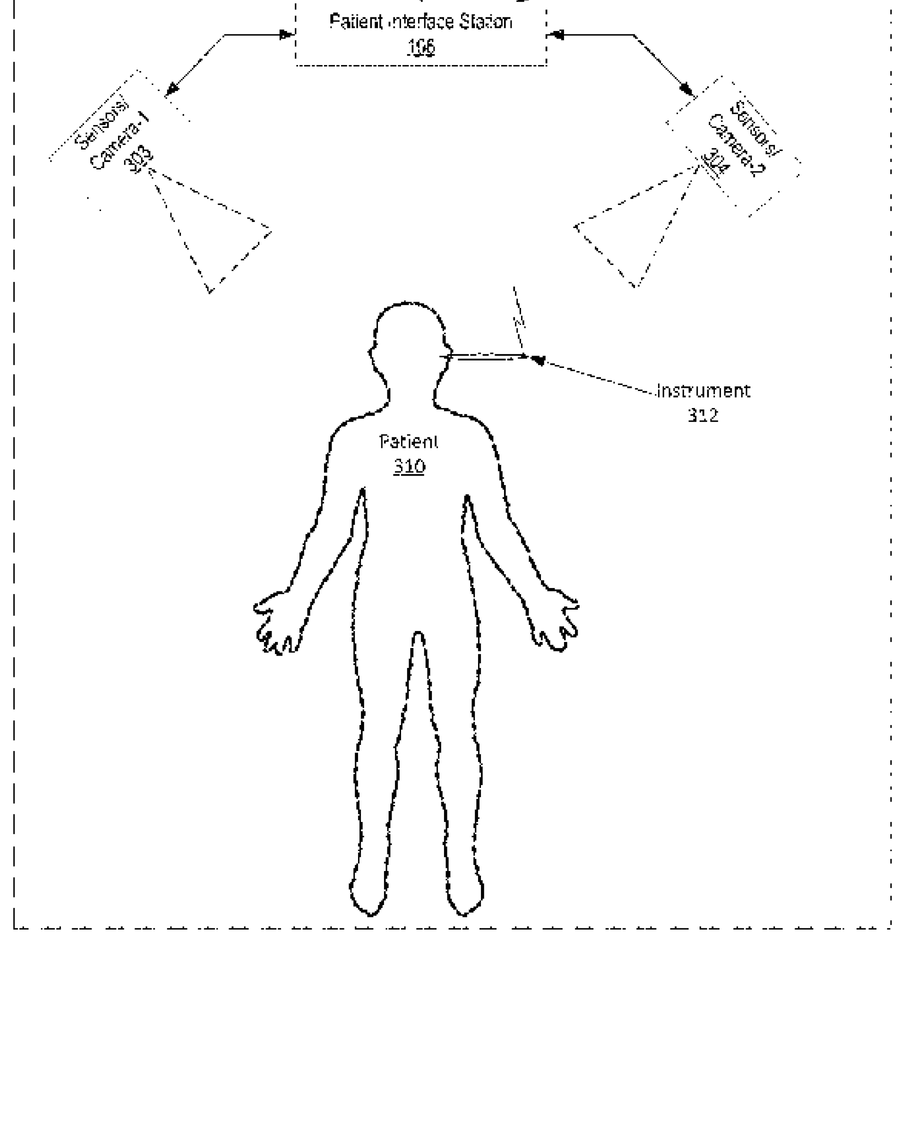
Primary Examiner — Oommen Jacob
(74) *Attorney, Agent, or Firm* — North Weber & Baugh LLP; Michael North

(57) **ABSTRACT**

Presented are systems and methods for the accurate acquisition of medical measurement data of a body part of patient. To assist in acquiring accurate medical measurement data, an automated diagnostic and treatment system provides instructions to the patient to allow the patient to precisely position a medical instrument in proximity to a target spot of a body part of patient. Based on a series of images acquired from a kiosk camera and an instrument camera, these instructions are generated. Subsequent images from instrument camera are analyzed by automated diagnostic and treatment system utilizing a database and deep convolution neural network (DCNN) to obtain measured medical data. An error threshold measurement by the automated diagnos-
(Continued)



tic and treatment system may determine the accuracy of the instrument positioning and the medical measured data. The measured medical data may be communicated to a physician.

9 Claims, 10 Drawing Sheets

(51) **Int. Cl.**

A61B 1/227	(2006.01)
A61B 1/24	(2006.01)
G06T 7/70	(2017.01)
G06T 7/00	(2017.01)
G06T 7/292	(2017.01)
A61B 3/12	(2006.01)

(52) **U.S. Cl.**
CPC ***A61B 3/12*** (2013.01); ***A61B 5/004*** (2013.01); ***A61B 5/0046*** (2013.01); ***A61B 5/7267*** (2013.01); ***A61B 5/7455*** (2013.01); ***G06T 7/292*** (2017.01); ***G06T 7/70*** (2017.01); ***G06T 7/97*** (2017.01); *G06T 2207/20081* (2013.01); *G06T 2207/30004* (2013.01)

(58) **Field of Classification Search**
CPC A61B 1/00108; A61B 5/004; A61B 34/20; A61B 3/12; A61B 5/6889; A61B 5/7264; A61B 5/0077; A61B 5/107; A61B 5/6888; A61B 1/227; A61B 1/00009; A61B 1/00147; A61B 5/7267; A61B 5/7455; A61B 90/36; A61B 1/00016; A61B 1/24; A61B 5/0046; A61B 2034/2055; A61B 2090/371; A61B 5/7405; A61B 34/10; A61B 2034/2048; A61B 2034/2065; A61B 2090/364; A61B 2017/00203; A61B 2090/365; A61B 2090/3945; A61B 2090/3937; A61B 2017/00221; A61B 2090/372; A61B 5/742; G06T 7/97; G06T 7/70; G06T 7/292; G06T 2207/20081; G06T 2207/30004; G16H 50/20; G16H 40/63; G06N 3/0454
See application file for complete search history.

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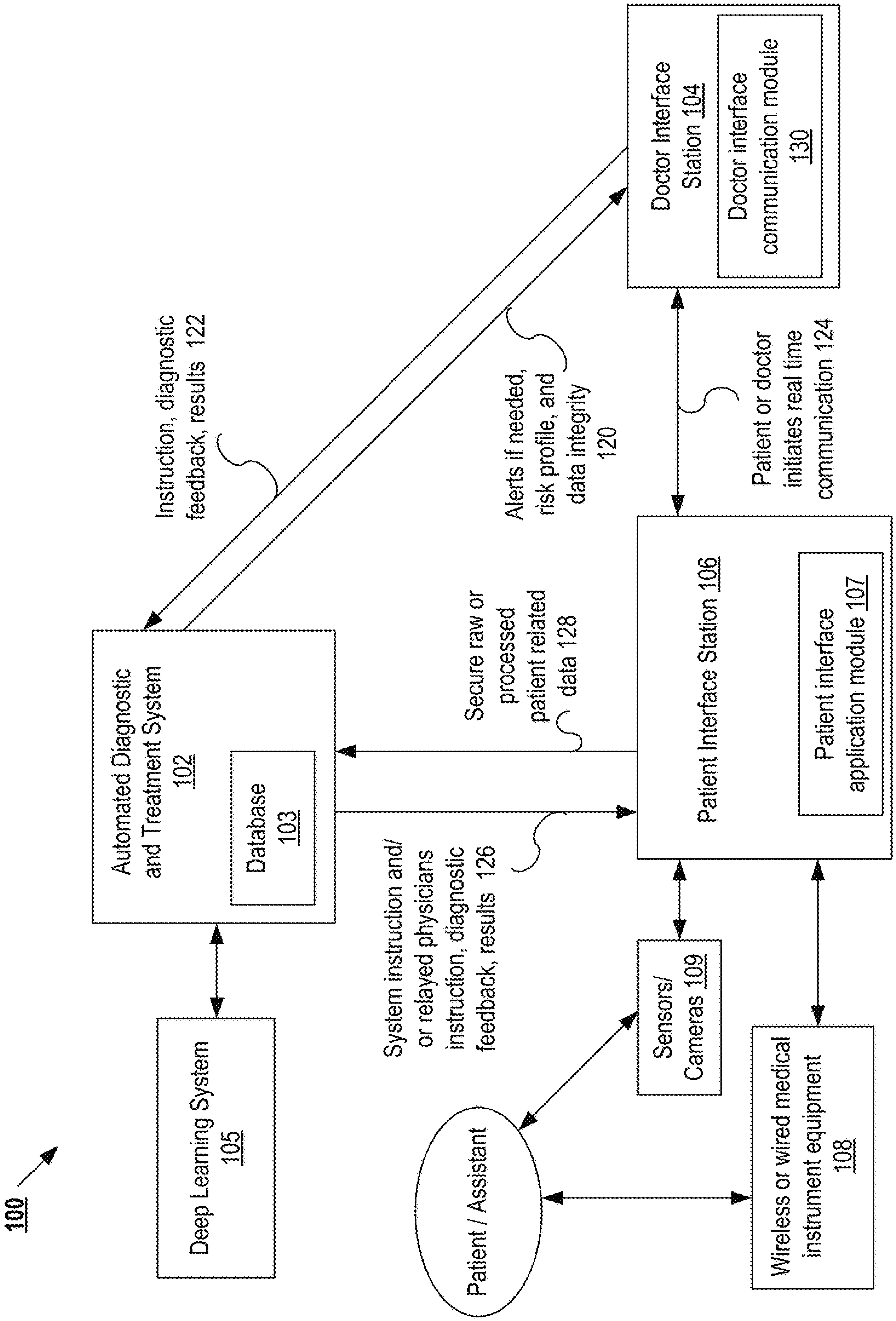

100
Automated Diagnostic and Treatment System 102
Database 103
Deep Learning System 105
Doctor Interface Station 104
Doctor interface communication module 130
Instruction, diagnostic feedback, results 122
Alerts if needed, risk profile, and data integrity 120
Patient or doctor initiates real time communication 124
Secure raw or processed patient related data 128
System instruction and/ or relayed physicians instruction, diagnostic feedback, results 126
Patient Interface Station 106
Patient interface application module 107
Sensors/ Cameras 109
Wireless or wired medical instrument equipment 108
Patient / Assistant

FIG. 1

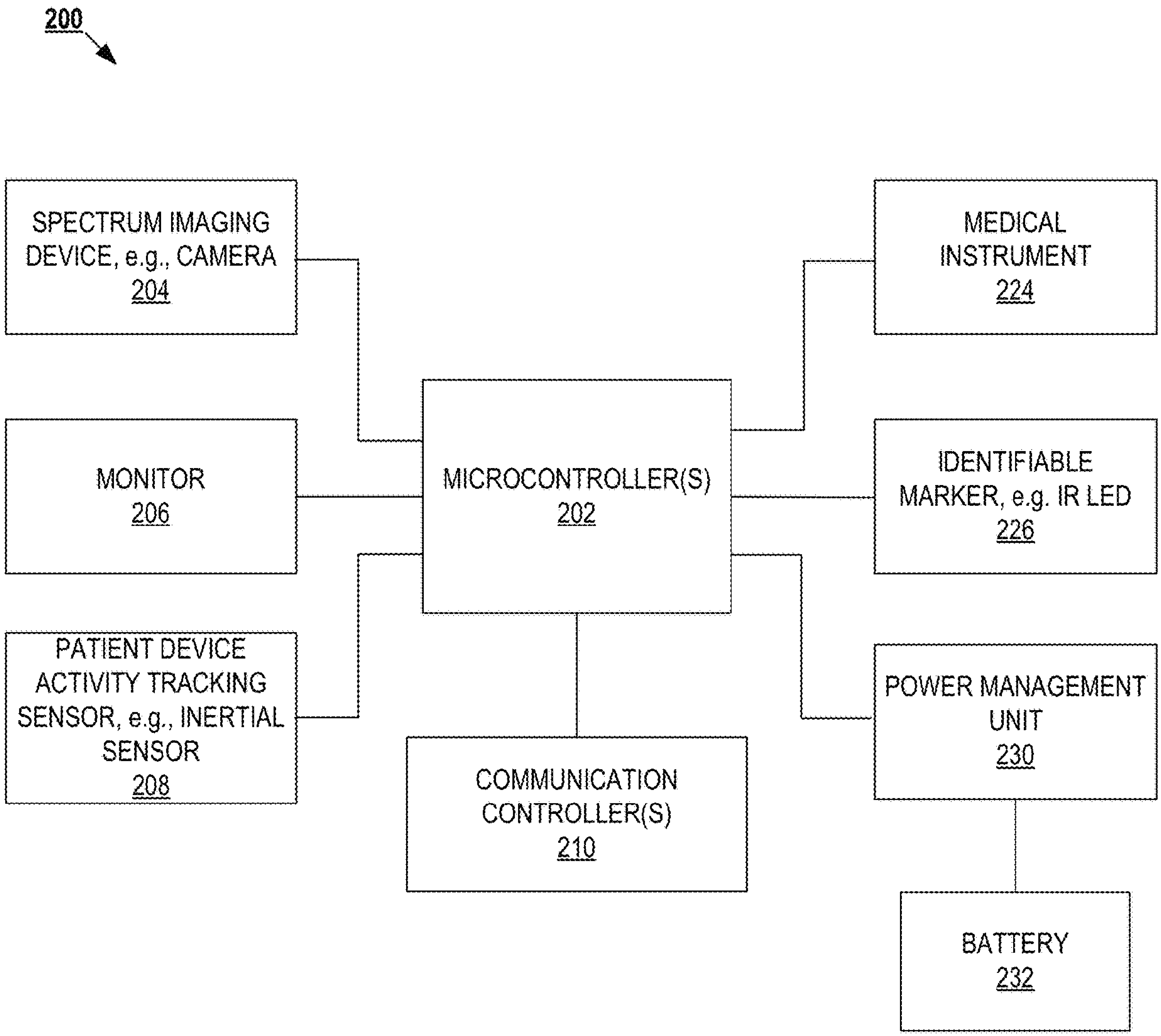

200
SPECTRUM IMAGING DEVICE, e.g., CAMERA 204
MONITOR 206
PATIENT DEVICE ACTIVITY TRACKING SENSOR, e.g., INERTIAL SENSOR 208
MICROCONTROLLER(S) 202
COMMUNICATION CONTROLLER(S) 210
MEDICAL INSTRUMENT 224
IDENTIFIABLE MARKER, e.g. IR LED 226
POWER MANAGEMENT UNIT 230
BATTERY 232

FIG. 2

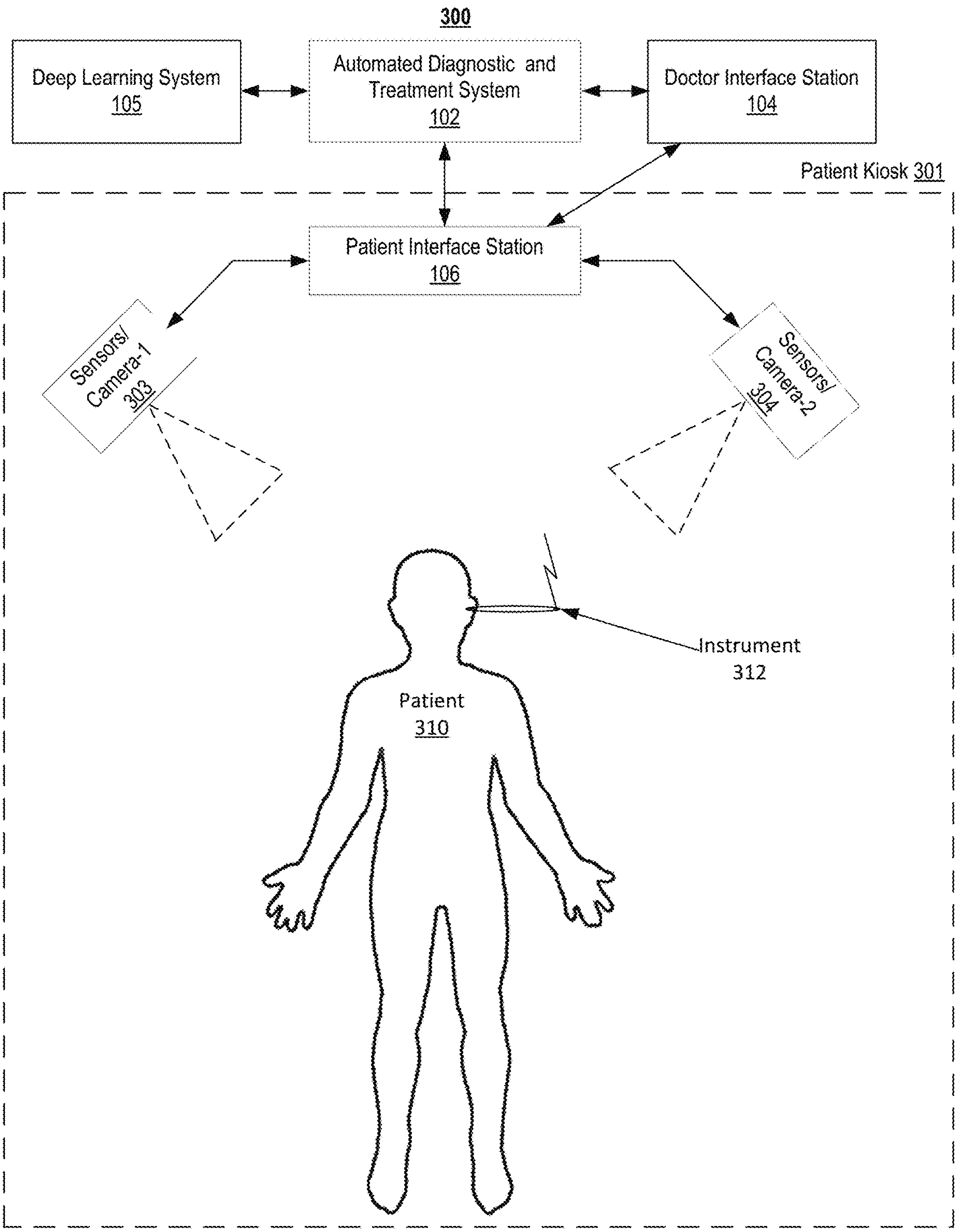

300
Deep Learning System
105
Automated Diagnostic and Treatment System
102
Doctor Interface Station
104
Patient Kiosk 301
Patient Interface Station
106
Sensors/ Camera-1
303
Sensors/ Camera-2
304
Instrument
312
Patient
310

FIG. 3A

320

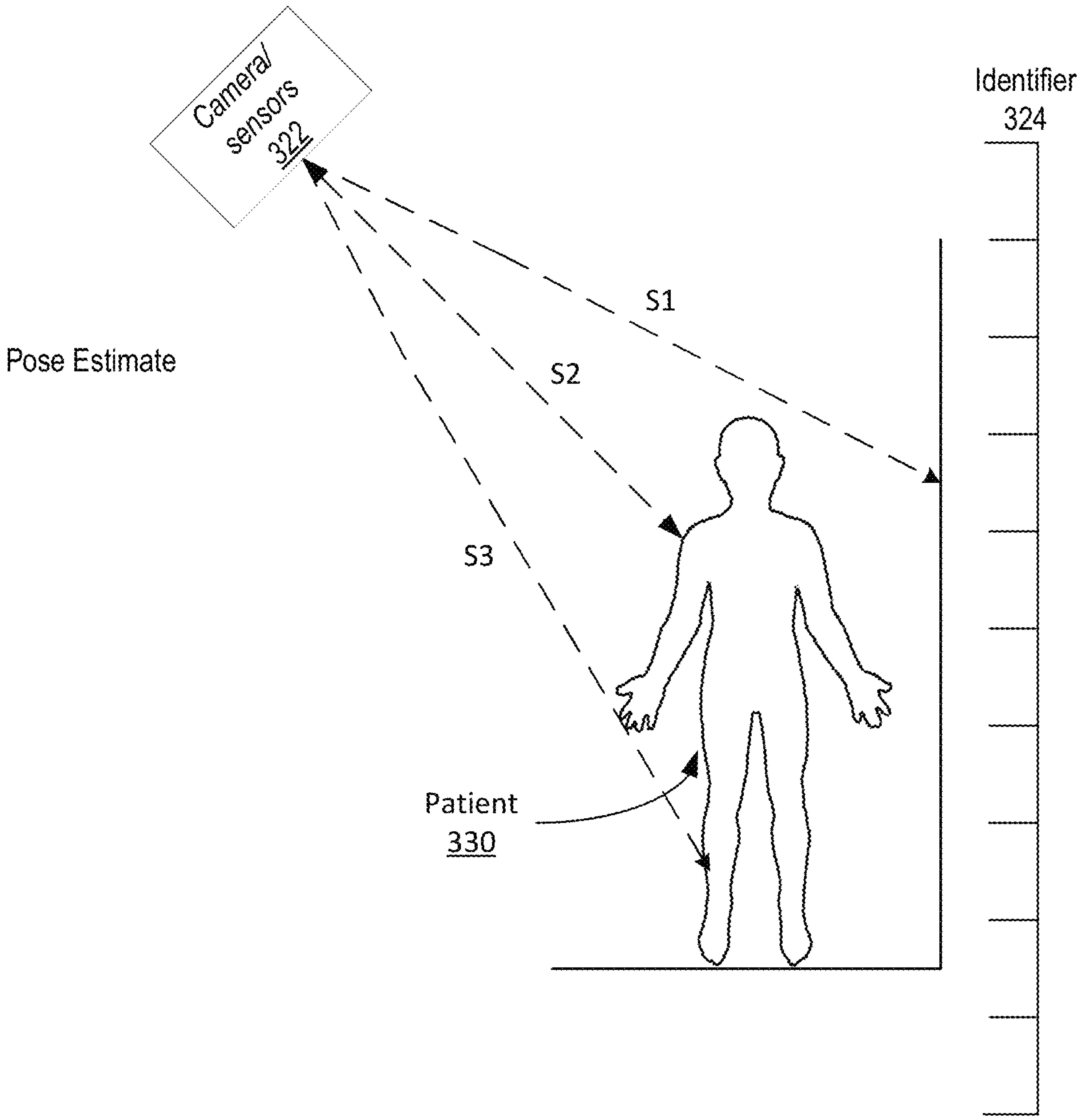
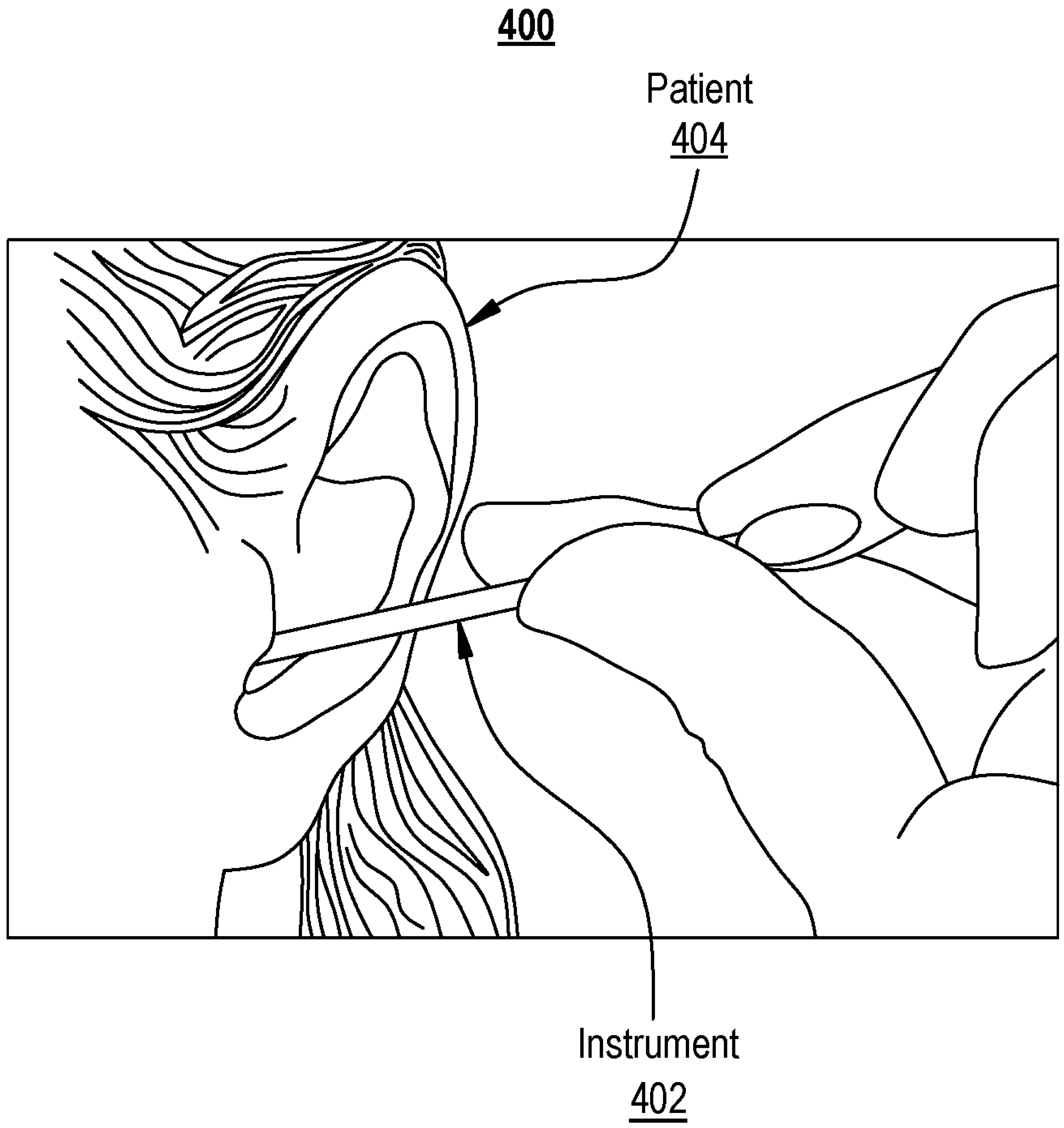

Camera/
sensors
322
Identifier
324
S1
S2
S3
Pose Estimate
Patient
330

FIG. 3B


400
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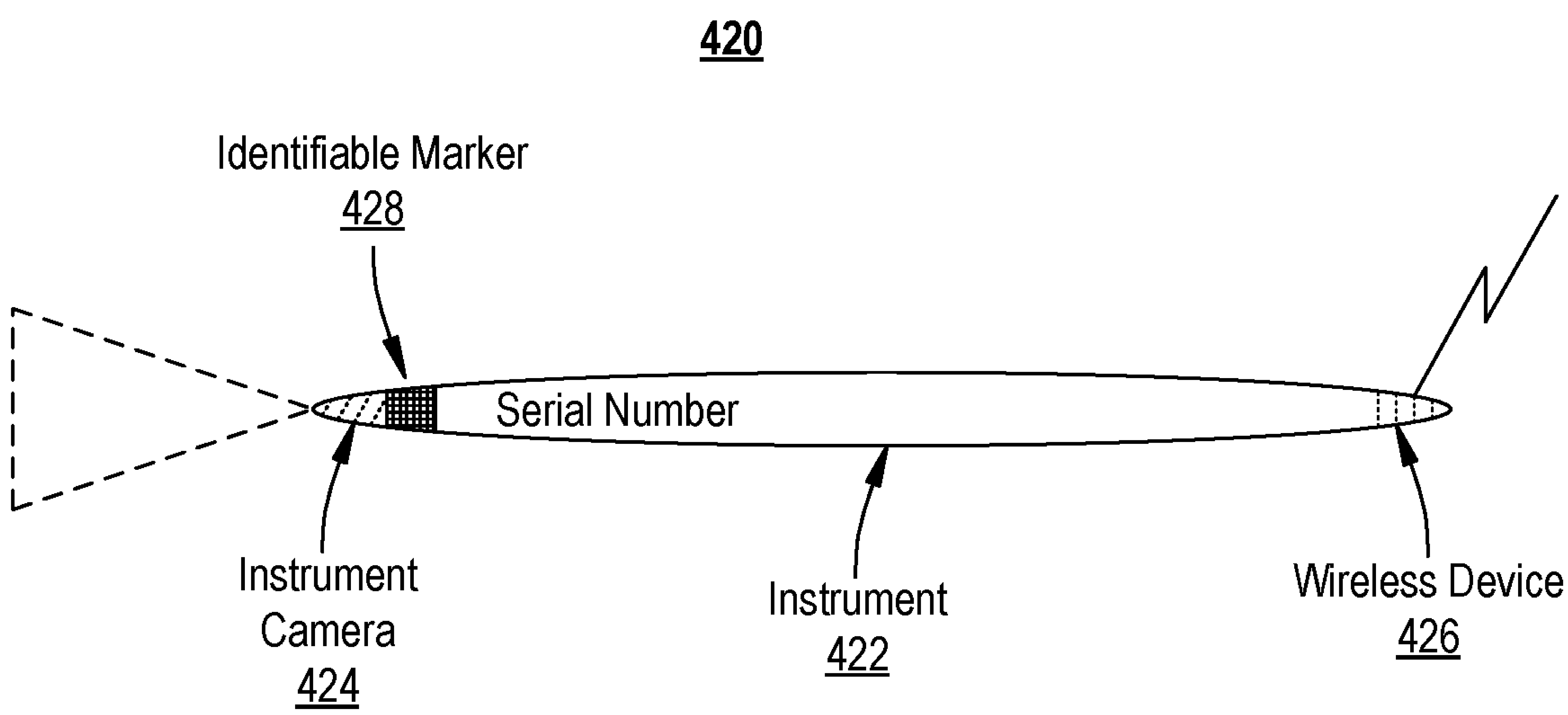
404
Instrument
402

FIG. 4A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Identifiable Marker
428
Serial Number
Instrument
Camera
424
Instrument
422
Wireless Device
426

FIG. 4B

440

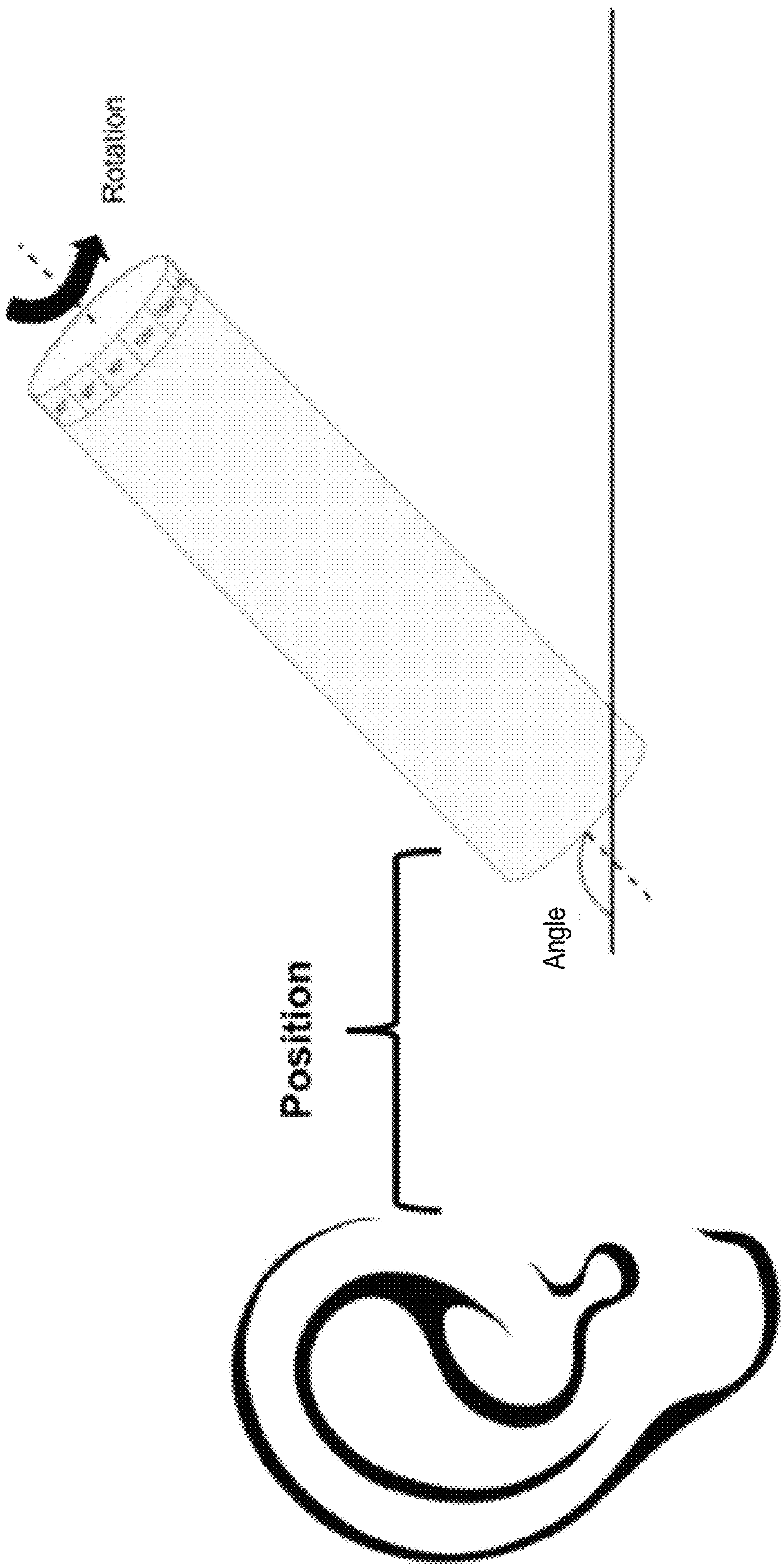

FIG. 4C

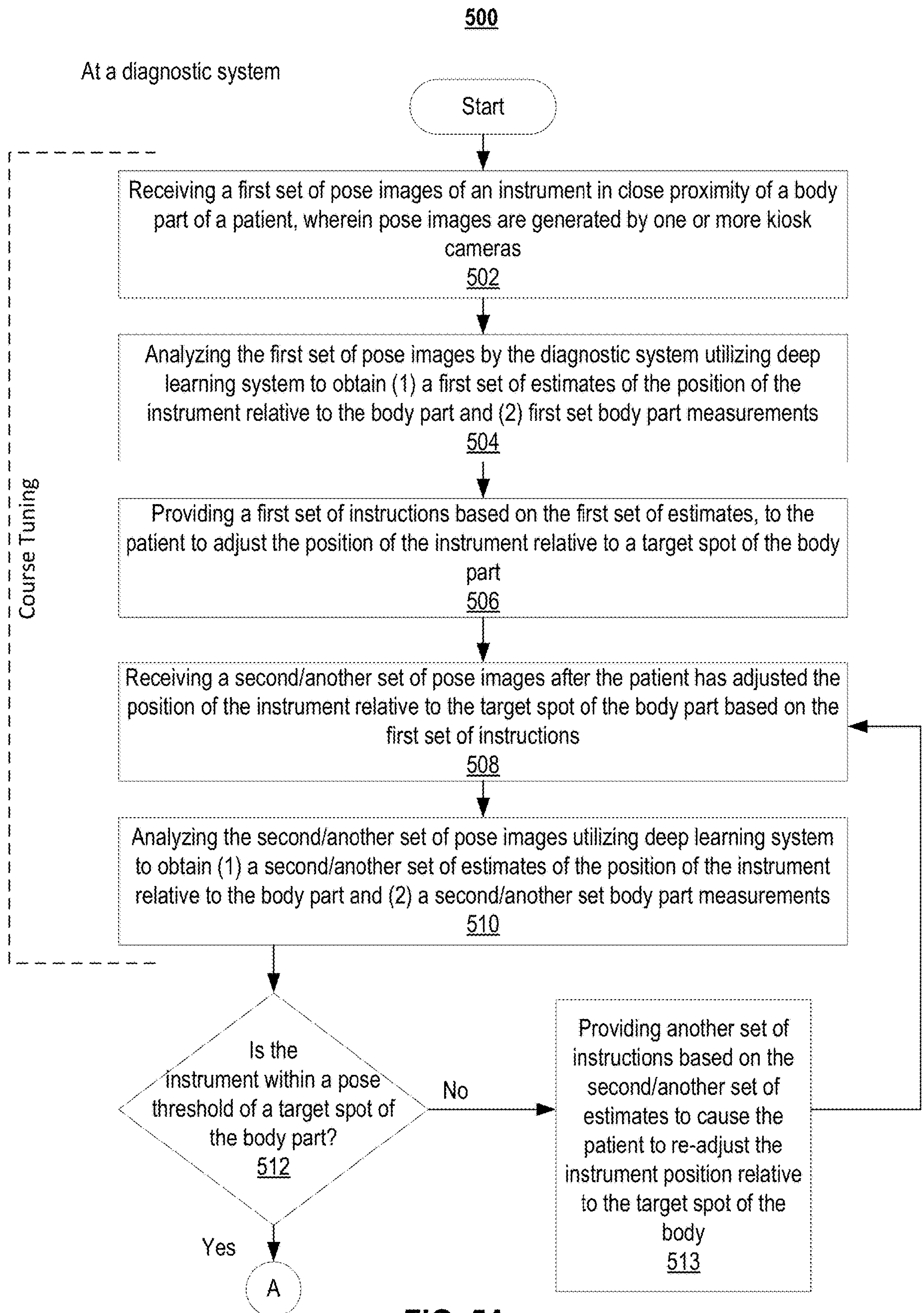
500
At a diagnostic system
Start
Receiving a first set of pose images of an instrument in close proximity of a body part of a patient, wherein pose images are generated by one or more kiosk cameras
502
Analyzing the first set of pose images by the diagnostic system utilizing deep learning system to obtain (1) a first set of estimates of the position of the instrument relative to the body part and (2) first set body part measurements
504
Providing a first set of instructions based on the first set of estimates, to the patient to adjust the position of the instrument relative to a target spot of the body part
506
Receiving a second/another set of pose images after the patient has adjusted the position of the instrument relative to the target spot of the body part based on the first set of instructions
508
Analyzing the second/another set of pose images utilizing deep learning system to obtain (1) a second/another set of estimates of the position of the instrument relative to the body part and (2) a second/another set body part measurements
510
Course Tuning
Is the instrument within a pose threshold of a target spot of the body part?
512
No
Providing another set of instructions based on the second/another set of estimates to cause the patient to re-adjust the instrument position relative to the target spot of the body
513
Yes
A

FIG. 5A

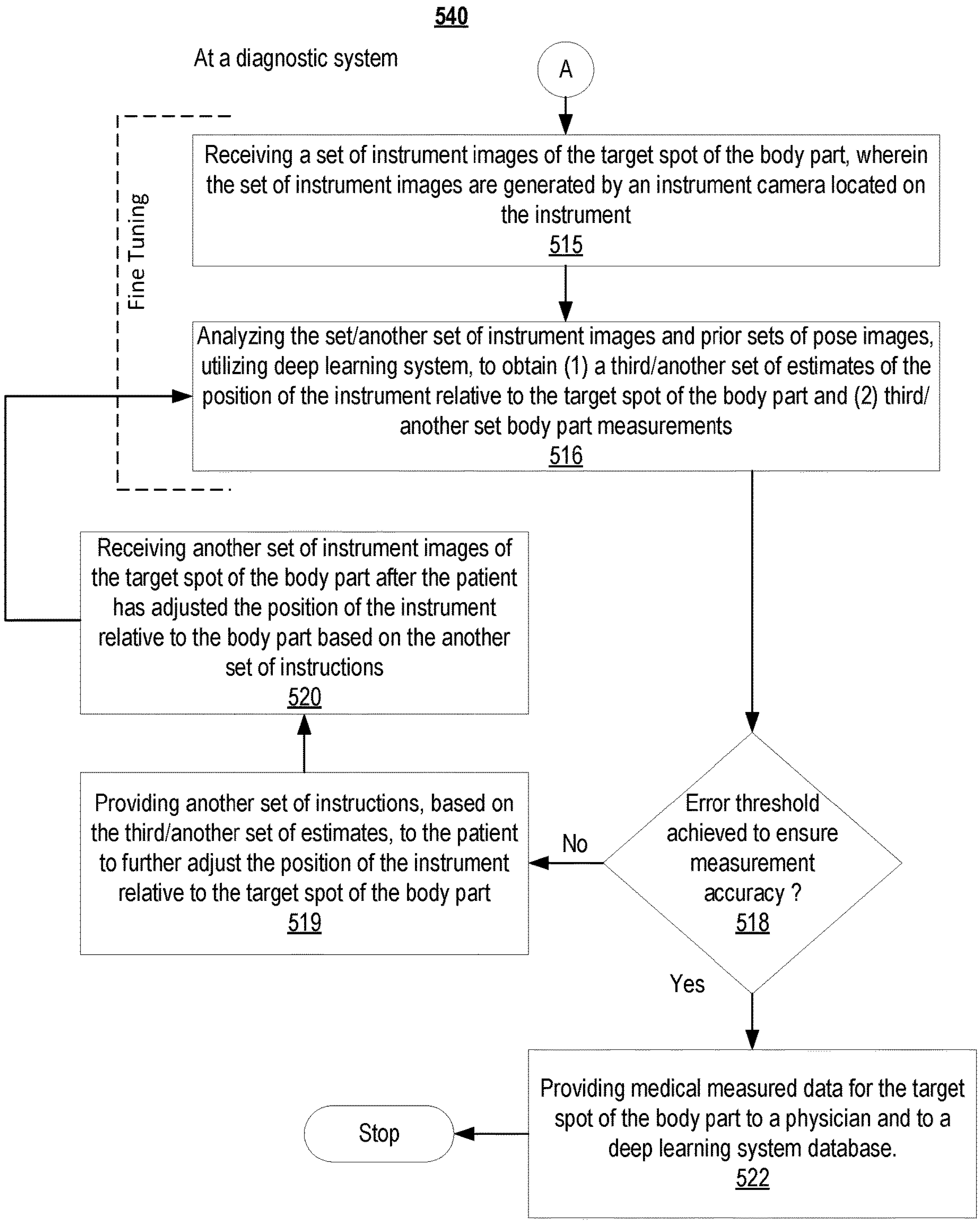
540
At a diagnostic system
A
Fine Tuning
Receiving a set of instrument images of the target spot of the body part, wherein the set of instrument images are generated by an instrument camera located on the instrument
515
Analyzing the set/another set of instrument images and prior sets of pose images, utilizing deep learning system, to obtain (1) a third/another set of estimates of the position of the instrument relative to the target spot of the body part and (2) third/another set body part measurements
516
Receiving another set of instrument images of the target spot of the body part after the patient has adjusted the position of the instrument relative to the body part based on the another set of instructions
520
Providing another set of instructions, based on the third/another set of estimates, to the patient to further adjust the position of the instrument relative to the target spot of the body part
519
No
Error threshold achieved to ensure measurement accuracy ?
518
Yes
Providing medical measured data for the target spot of the body part to a physician and to a deep learning system database.
522
Stop

FIG. 5B

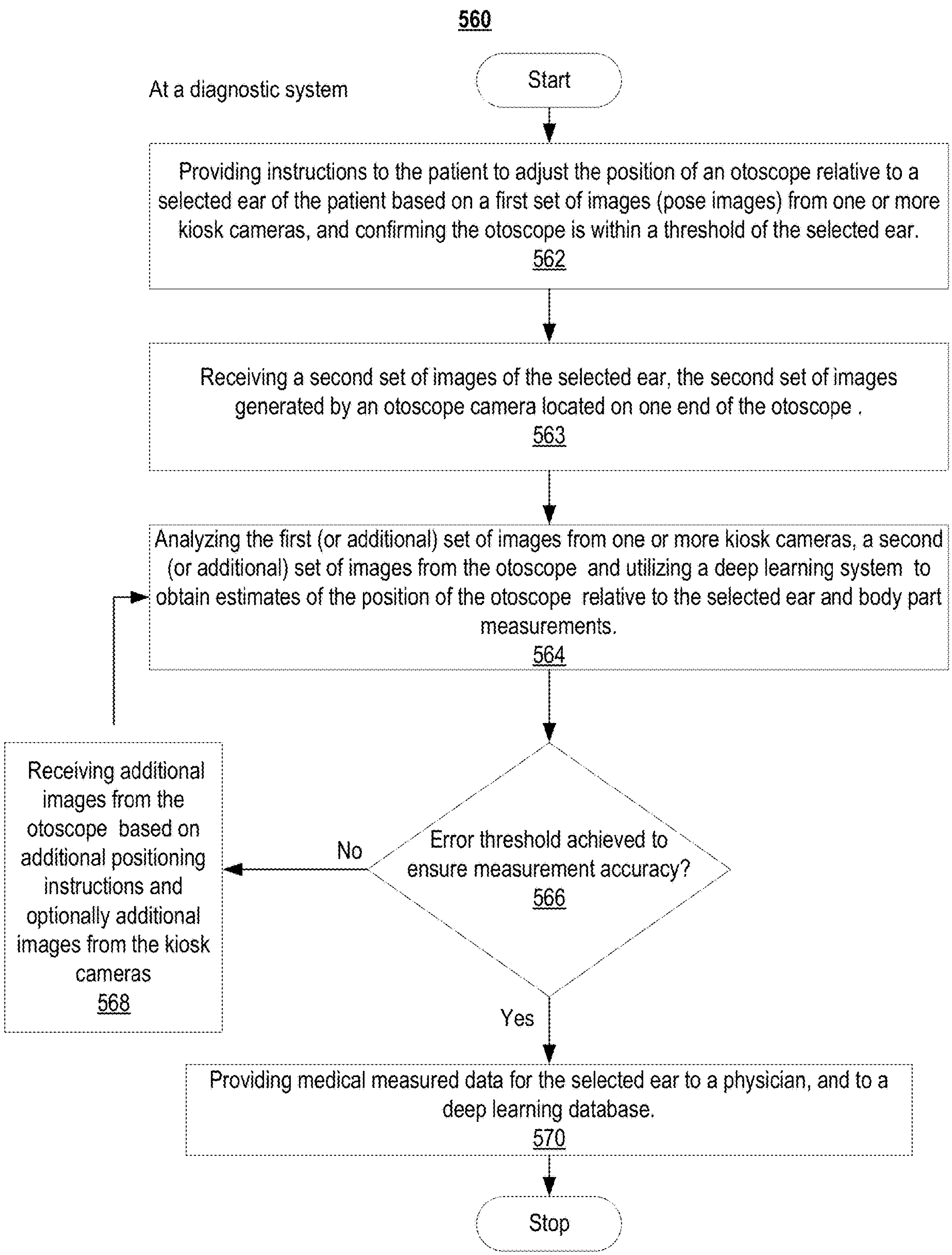
560
At a diagnostic system
Start
Providing instructions to the patient to adjust the position of an otoscope relative to a selected ear of the patient based on a first set of images (pose images) from one or more kiosk cameras, and confirming the otoscope is within a threshold of the selected ear.
562
Receiving a second set of images of the selected ear, the second set of images generated by an otoscope camera located on one end of the otoscope .
563
Analyzing the first (or additional) set of images from one or more kiosk cameras, a second (or additional) set of images from the otoscope and utilizing a deep learning system to obtain estimates of the position of the otoscope relative to the selected ear and body part measurements.
564
Error threshold achieved to ensure measurement accuracy?
566
No
Receiving additional images from the otoscope based on additional positioning instructions and optionally additional images from the kiosk cameras
568
Yes
Providing medical measured data for the selected ear to a physician, and to a deep learning database.
570
Stop

FIG. 5C

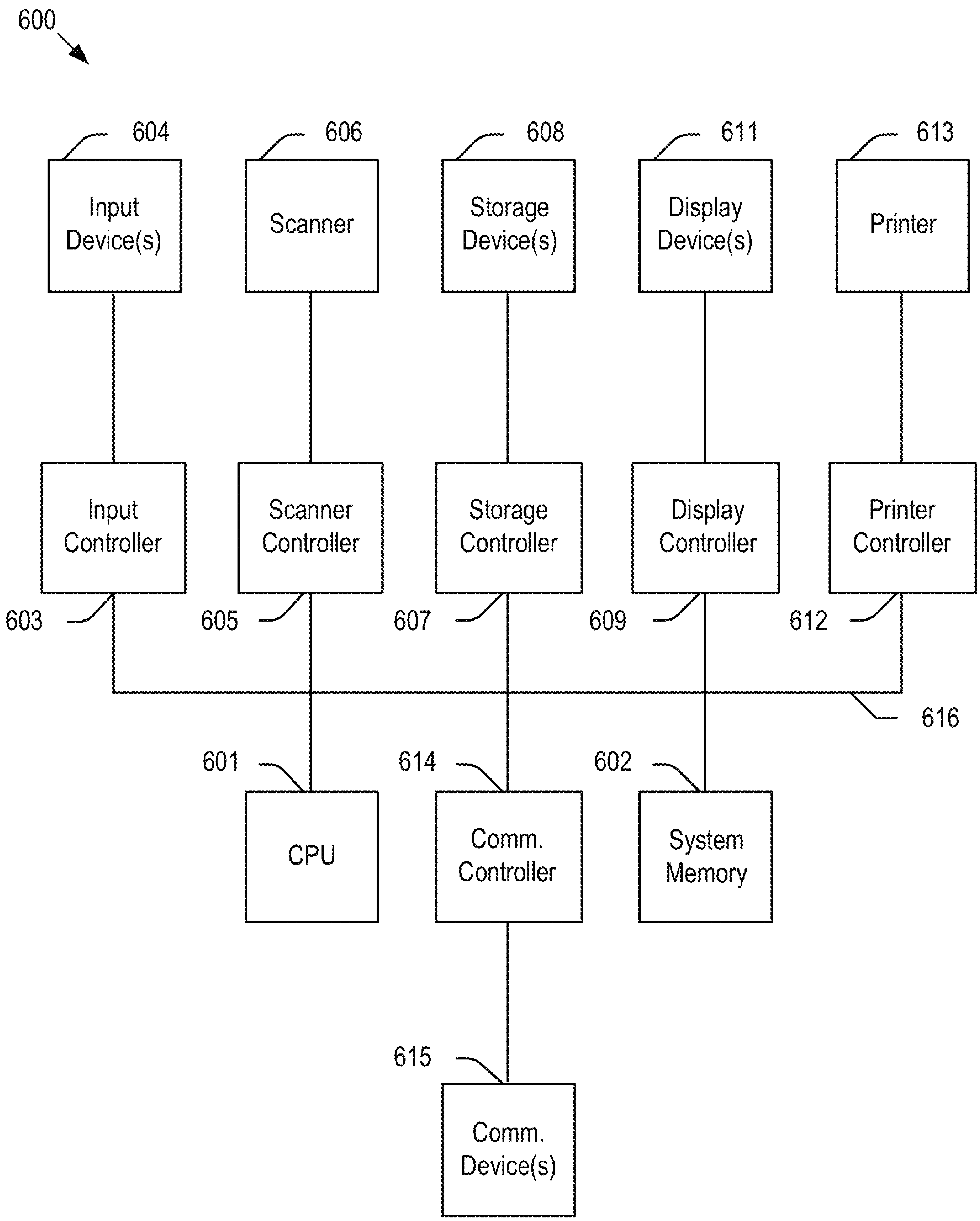
600
604
Input Device(s)
606
Scanner
608
Storage Device(s)
611
Display Device(s)
613
Printer
Input Controller
Scanner Controller
Storage Controller
Display Controller
Printer Controller
603
605
607
609
612
616
601
614
602
CPU
Comm. Controller
System Memory
615
Comm. Device(s)

FIG. 6

SYSTEMS AND METHODS FOR OPTICAL MEDICAL INSTRUMENT PATIENT MEASUREMENTS

BACKGROUND

Technical Field

The present disclosure relates to computer-assisted health care, and more particularly, to systems and methods for providing a computer-assisted medical diagnostic architecture in which a patient is able to perform certain medical measurements with the assistance of a medical kiosk or medical camera system.

Background of the Invention

One skilled in the art will recognize the importance of addressing the ever-increasing cost of providing consistent, high-quality medical care to patients. Governmental agencies and insurance companies are attempting to find solutions that reduce the cost of medical care without significantly reducing the quality of medical examinations provided by doctors and nurses. Through consistent regulation changes, electronic health record changes and pressure from payers, both health care facilities and providers are looking for ways to make patient intake, triage, diagnosis, treatment, electronic health record data entry, treatment, billing, and patient follow-up activity more efficient, provide better patient experience, and increase the doctor to patient throughput per hour, while simultaneously reducing cost.

The desire to increase access to health care providers, a pressing need to reduce health care costs in developed countries and the goal of making health care available to a larger population in less developed countries have fueled the idea of telemedicine. In most cases, however, video or audio conferencing with a doctor does not provide sufficient patient-physician interaction that is necessary to allow for a proper medical diagnosis to efficiently serve patients.

What is needed are systems and methods that ensure reliable remote or local medical patient intake, triage, diagnosis, treatment, electronic health record data entry/management, treatment, billing and patient follow-up activity so that physicians can allocate patient time more efficiently and, in some instances, allow individuals to manage their own health, thereby, reducing health care costs.

BRIEF DESCRIPTION OF THE DRAWINGS

References will be made to embodiments of the invention, examples of which may be illustrated in the accompanying figures. These figures are intended to be illustrative, not limiting. Although the invention is generally described in the context of these embodiments, it should be understood that it is not intended to limit the scope of the invention to these particular embodiments.

FIG. **1** illustrates an exemplary medical diagnostic system according to embodiments of the present disclosure.

FIG. **2** illustrates an exemplary medical instrument equipment system according to embodiments of the present disclosure.

FIG. **3**A illustrates an exemplary system for measuring a patient's body parts utilizing optical medical instruments and deep learning systems according to embodiments of the present disclosure.

FIG. **3**B illustrates another exemplary system for measuring a patient's body parts utilizing cameras and sensors according to embodiments of the present disclosure

FIG. **4**A illustrates an exemplary method of measuring a patient's body part utilizing an optical medical instrument according to embodiments of the present disclosure.

FIG. **4**B illustrates an exemplary optical medical instrument according to embodiments of the present disclosure.

FIG. **4**C illustrates an exemplary optical medical instrument being positioned at an angle, position, and rotation according to embodiments of the present disclosure.

FIG. **5**A is a flowchart of an illustrative method for making accurate medical instrument patient measurements, according to embodiments of the present disclosure.

FIG. **5**B is another flowchart of an illustrative method for making accurate medical instrument patient measurements, according to embodiments of the present disclosure.

FIG. **5**C is yet another flowchart of an illustrative method for making accurate medical instrument patient measurements, according to embodiments of the present disclosure.

FIG. **6** depicts a simplified block diagram of a computing device/information handling system according to embodiments of the present disclosure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following description, for purposes of explanation, specific details are set forth in order to provide an understanding of the disclosure. It will be apparent, however, to one skilled in the art that the disclosure can be practiced without these details. Furthermore, one skilled in the art will recognize that embodiments of the present disclosure, described below, may be implemented in a variety of ways, such as a process, an apparatus, a system, a device, or a method on a tangible computer-readable medium.

Elements/components shown in diagrams are illustrative of exemplary embodiments of the disclosure and are meant to avoid obscuring the disclosure. It shall also be understood that throughout this discussion that components may be described as separate functional units, which may comprise sub-units, but those skilled in the art will recognize that various components, or portions thereof, may be divided into separate components or may be integrated together, including integrated within a single system or component. It should be noted that functions or operations discussed herein may be implemented as components/elements. Components/elements may be implemented in software, hardware, or a combination thereof.

Furthermore, connections between components or systems within the figures are not intended to be limited to direct connections. Rather, data between these components may be modified, re-formatted, or otherwise changed by intermediary components. Also, additional or fewer connections may be used. Also, additional or fewer connections may be used. It shall also be noted that the terms "coupled" "connected" or "communicatively coupled" shall be understood to include direct connections, indirect connections through one or more intermediary devices, and wireless connections.

Reference in the specification to "one embodiment," "preferred embodiment," "an embodiment," or "embodiments" means that a particular feature, structure, characteristic, or function described in connection with the embodiment is included in at least one embodiment of the disclosure and may be in more than one embodiment. The appearances of the phrases "in one embodiment," "in an embodiment," or "in embodiments" in various places in the specification are not necessarily all referring to the same embodiment or embodiments. The terms "include," "including," "comprise," and "comprising" shall be understood to be open terms and any lists that follow are examples and not meant to be limited to the listed items. Any headings used herein are for organizational purposes only and shall not be used to limit the scope of the description or the claims.

Furthermore, the use of certain terms in various places in the specification is for illustration and should not be construed as limiting. A service, function, or resource is not limited to a single service, function, or resource; usage of these terms may refer to a grouping of related services, functions, or resources, which may be distributed or aggregated.

In this document, the term "sensor" refers to a device capable of acquiring information related to any type of physiological condition or activity (e.g., a biometric diagnostic sensor); physical data (e.g., a weight); and environmental information (e.g., ambient temperature sensor), including hardware-specific information. The term "position" refers to spatial and temporal data (e.g. orientation and motion information). The position data may be, for example, but without limitations, 2-dimensional (2D), 2.5-dimensional (2.5D), or true 3-dimensional (3D) data representation. "Doctor" refers to any health care professional, health care provider, physician, or person directed by a physician. "Patient" is any user who uses the systems and methods of the present invention, e.g., a person being examined or anyone assisting such person. The term illness may be used interchangeably with the term diagnosis. As used herein, "answer" or "question" refers to one or more of 1) an answer to a question, 2) a measurement or measurement request (e.g., a measurement performed by a "patient"), and 3) a symptom (e.g., a symptom selected by a "patient").

FIG. **1** illustrates an exemplary medical diagnostic system according to embodiments of the present disclosure. Diagnostic system **100** comprises automated diagnostic and treatment system **102**, patient interface station **106**, doctor interface station **104**, deep learning system **105**, sensors/cameras **109** and medical instrument equipment **108**. Deep learning system **105** may include, for example, but without limitations, deep convolution neural network (DCNN), Multi-layer preceptrons (MLP), Fully Convolutional Networks (FCNs), Capsule Networks, and artificial neural networks (A-NNs). Both patient interface station **106** and doctor interface station **104** may be implemented into any tablet, computer, mobile device, or other electronic device. Deep learning system **105** utilizes artificial reality feedback to assist the automated diagnostic and treatment system **102** to obtain improved medical measurements by the medical instrument equipment **108**. Deep learning may be a name referring to the use of "stacked neural networks"; that is, networks composed of several layers. The layers are made of nodes, where a node is just a place where computation occurs and is loosely patterned on a neuron in the human brain. The neuron in the brain fires when it encounters sufficient stimuli. Deep learning system **105** may be used in computer vision and have also have been applied to acoustic modeling for automatic speech recognition (ASR).

Patient interface station **106** comprises patient interface application module **107** and is coupled to sensors/cameras **109**. In turn, sensors/cameras **109** may monitor and may capture images of the patient/assistant. Patient interface station **106** receives from the automated diagnostic and treatment system **102** system instruction and/or relayed physicians instruction, diagnostic feedback, results **126**. Patient interface station **106** sends to the automated diagnostic and treatment system **102** secure raw or processed patient-related data **128**. Patient interface station **106** also provides interfaces between sensors/cameras **109**, located in the patient interface station **106**, and the patient/assistant. Patient interface station **106** also provides interfaces to medical instrument equipment **108**. Medical instrument equipment **108** may be, for example, but without limitations, an ophthalmoscope, intraoral camera, auriscope, or otoscope.

Medical instrument equipment **108** is designed to collect mainly diagnostic patient data, and may comprise one or more diagnostic devices, for example, in a home diagnostic medical kit that generates diagnostic data based on physical and non-physical characteristics of a patient. It is noted that diagnostic system **100** may comprise additional sensors and devices that, in operation, collect, process, or transmit characteristic information about the patient, medical instrument usage, orientation, environmental parameters such as ambient temperature, humidity, location, and other useful information that may be used to accomplish the objectives of the present invention.

In operation, a patient may enter patient-related data, such as health history, patient characteristics, symptoms, health concerns, medical instrument measured diagnostic data, images, and sound patterns, or other relevant information into patient interface station **106**. The patient may use any means of communication, such as voice control, to enter data, e.g., in the form of a questionnaire. Patient interface station **106** may provide the data raw or in processed form to automated diagnostic and treatment system **102**, e.g., via a secure communication.

In embodiments, the patient may be prompted, e.g., by a software application, to answer questions intended to aid in the diagnosis of one or more medical conditions. The software application may provide guidance by describing how to use medical instrument equipment **108** to administer a diagnostic test or how to make diagnostic measurements for any particular device that may be part of medical instrument equipment **108** so as to facilitate accurate measurements of patient diagnostic data.

In embodiments, the patient may use medical instrument equipment **108** to create a patient health profile that serves as a baseline profile. Gathered patient-related data may be securely stored in database **103** or a secure remote server (not shown) coupled to automated diagnostic and treatment system **102**. In embodiments, automated diagnostic and treatment system **102**, supported by and deep learning system **105**, enables interaction between a patient and a remotely located health care professional, who may provide instructions to the patient, e.g., by communicating via the software application. A doctor may log into a cloud-based system (not shown) to access patient-related data via doctor interface station **104**. The doctor interface station **104** comprises a doctor interface communication module **130**. In embodiments, automated diagnostic and treatment system **102** presents automated diagnostic suggestions to a doctor, who may verify or modify the suggested information. Automated diagnostic and treatment system **102** is coupled to doctor interface station **104**. Automated diagnostic and treatment system **102** may communicate to doctor interface station **104** alerts, if needed, risk profile, and data integrity **120**.

In embodiments, based on one more patient questionnaires, data gathered by medical instrument equipment **108**, patient feedback, and historic diagnostic information, the patient may be provided with instructions, feedback, results

122, and other information pertinent to the patient's health. In embodiments, the doctor may select an illness based on automated diagnostic system suggestions and/or follow a sequence of instructions, feedback, and/or results **122** may be adjusted based on decision vectors associated with a medical database. In embodiments, medical instrument equipment **108** uses the decision vectors to generate a diagnostic result, e.g., in response to patient answers and/or measurements of the patient's vital signs.

In embodiments, medical instrument equipment **108** comprises a number of sensors, such as accelerometers, gyroscopes, pressure sensors, cameras, bolometers, altimeters, IR LEDs, and proximity sensors that may be coupled to one or more medical devices, e.g., a thermometer, to assist in performing diagnostic measurements and/or monitor a patient's use of medical instrument equipment **108** for accuracy. A camera, bolometer, or other spectrum imaging device (e.g. radar), in addition to taking pictures of the patient, may use image or facial recognition software and machine vision to recognize body parts, items, and actions to aid the patient in locating suitable positions for taking a measurement on the patient's body, e.g., by identifying any part of the patient's body as a reference.

Examples of the types of diagnostic data that medical instrument equipment **108** may generate comprise body temperature, blood pressure, images, sound, heart rate, blood oxygen level, motion, ultrasound, pressure or gas analysis, continuous positive airway pressure, electrocardiogram, electroencephalogram, electrocardiography, BMI, muscle mass, blood, urine, and any other patient-related data **128**. In embodiments, patient-related data **128** may be derived from a non-surgical wearable or implantable monitoring device that gathers sample data.

In embodiments, an IR LED, proximity beacon, or other identifiable marker (not shown) may be attached to medical instrument equipment **108** to track the position and placement of medical instrument equipment **108**. In embodiments, a camera, bolometer, or other spectrum imaging device uses the identifiable marker as a control tool to aid the camera or the patient in determining the position of medical instrument equipment **108**.

In embodiments, a deep learning system **105**, which may include machine vision software, may be used to track and overlay or superimpose, e.g., on a screen, the position of the identifiable marker e.g., IR LED, heat source, or reflective material with a desired target location at which the patient should place medical instrument equipment **108**, thereby, aiding the patient to properly place or align a sensor and ensure accurate and reliable readings. Once medical instrument equipment **108**, e.g., a stethoscope is placed at the desired target location on a patient's torso, the patient may be prompted by optical or visual cues to breath according to instructions or perform other actions to facilitate medical measurements and to start a measurement.

In embodiments, one or more sensors that may be attached to medical instrument equipment **108** monitor the placement and usage of medical instrument equipment **108** by periodically or continuously recording data and comparing measured data, such as location, movement, rotation and angles, to an expected data model and/or an error threshold to ensure measurement accuracy. A patient may be instructed to adjust an angle, location, rotation or motion of medical instrument equipment **108**, e.g., to adjust its state and, thus, avoid low-accuracy or faulty measurement readings. In embodiments, sensors attached or tracking medical instrument equipment **108** may generate sensor data and patient interaction activity data that may be compared, for example, against an idealized patient medical instrument equipment usage sensor model data to create an equipment usage accuracy score. The patient medical instrument equipment measured medical data may also be compared with idealized device measurement data expected from medical instrument equipment **108** to create a device accuracy score. Recording bioelectric signals may include, for example, but without limitations, electroencephalography, electrocardiography, electrooculography, electromyography and electrogastrography.

Feedback from medical instrument equipment **108** (e.g., sensors, proximity, camera, etc.) and actual device measurement data may be used to instruct the patient to properly align medical instrument equipment **108** during a measurement. In embodiments, medical instrument equipment type and sensor system monitoring of medical instrument equipment **108** patient interaction may be used to create a device usage accuracy score for use in a medical diagnosis algorithm. Similarly, patient medical instrument equipment measured medical data may be used to create a measurement accuracy score for use by the medical diagnostic algorithm. In embodiments, medical instrument equipment **108** may also be fitted with haptic/tactile feedback sensors which may augment audio or screen-based guidance instructions for taking measurement. These haptic feedback devices, or haptic feedback sensors, may include, but are not limited to, vibration motors (similar to those found in smart phones) fitted around the medical instrument equipment to give tactile instructions (e.g. vibration on the left side of the medical device to instruct the patient to move the medical device left), or flywheels to give kinesthetic feedback such as resisting movement in undesirable directions, and aiding movement in the correct direction (similar to certain virtual reality peripherals).

In embodiments, machine vision software may be used to show on a display an animation that mimics a patient's movements and provides detailed interactive instructions and real-time feedback to the patient. This aids the patient in correctly positioning and operating medical instrument equipment **108** relative to the patient's body so as to ensure a high level of accuracy when using medical instrument equipment **108** is operated. In embodiments, the display may be a traditional computer screen. In other embodiments, the display may be augmented/virtual/mixed reality hardware, where patients may interact with the kiosk in a completely virtual environment while wearing AR/VR goggles.

In embodiments, once automated diagnostic and treatment system **102** detects unexpected data, e.g., data representing an unwanted movement, location, measurement data, etc., a validation process comprising a calculation of a trustworthiness score or reliability factor is initiated in order to gauge the measurement accuracy. Once the accuracy of the measured data falls below a desired level, the patient may be asked to either repeat a measurement or request assistance by an assistant, who may answer questions, e.g., remotely via an application to help with proper equipment usage, or alert a nearby person to assist with using medical instrument equipment **108**. The validation process, may also instruct a patient to answer additional questions, and may comprise calculating the measurement accuracy score based on a measurement or re-measurement.

In embodiments, upon request **124**, automated diagnostic and treatment system **102** may enable a patient-doctor interaction by granting the patient and doctor access to diagnostic system **100**. The patient may enter data, take measurements, and submit images and audio files or any other information to the application or web portal. The doctor may access that information, for example, to review a diagnosis generated by automated diagnostic and treatment system **102**, and generate, confirm, or modify instructions for the patient. Patient-doctor interaction, while not required for diagnostic and treatment, if used, may occur in person, real-time via an audio/video application, or by any other means of communication.

In embodiments, automated diagnostic and treatment system **102** may utilize images generated from a diagnostic examination of mouth, throat, eyes, ears, skin, extremities, surface abnormalities, internal imaging sources, and other suitable images and/or audio data generated from diagnostic examination of heart, lungs, abdomen, chest, joint motion, voice, and any other audio data sources. Automated diagnostic and treatment system **102** may further utilize patient lab tests, medical images, or any other medical data. In embodiments, automated diagnostic and treatment system **102** enables medical examination of the patient, for example, using medical devices, e.g., ultrasound, in medical instrument equipment **108** to detect sprains, contusions, or fractures, and automatically provide diagnostic recommendations regarding a medical condition of the patient.

In embodiments, diagnosis comprises the use of medical database decision vectors that are at least partially based on the patient's self-measured (or assistant-measured) vitals or other measured medical data, the accuracy score of a measurement dataset, a usage accuracy score of a sensor attached to medical instrument equipment **108**, a regional illness trend, and information used in generally accepted medical knowledge evaluations steps. The decision vectors and associated algorithms, which may be installed in automated diagnostic and treatment system **102**, may utilize one or more-dimensional data, patient history, patient questionnaire feedback, and pattern recognition or pattern matching for classification using images and audio data. In embodiments, a medical device usage accuracy score generator (not shown) may be implemented within automated diagnostic and treatment system **102** and may utilize an error vector of any device in medical instrument equipment or attached medical instrument equipment **108** to create the device usage accuracy score and utilize the actual patient-measured device data to create the measurement data accuracy score.

In embodiments, automated diagnostic and treatment system **102** outputs diagnosis and/or treatment information that may be communicated to the patient, for example, electronically or in person by a medical professional, e.g., a treatment guideline that may include a prescription for a medication. In embodiments, prescriptions may be communicated directly to a pharmacy for pick-up or automated home delivery.

In embodiments, automated diagnostic and treatment system **102** may generate an overall health risk profile of the patient and recommend steps to reduce the risk of overlooking potentially dangerous conditions or guide the patient to a nearby facility that can treat the potentially dangerous condition. The health risk profile may assist a treating doctor in fulfilling duties to the patient, for example, to carefully review and evaluate the patient and, if deemed necessary, refer the patient to a specialist, initiate further testing, etc. The health risk profile advantageously reduces the potential for negligence and, thus, medical malpractice.

Automated diagnostic and treatment system **102**, in embodiments, comprises a payment feature that uses patient identification information to access a database to, e.g., determine whether a patient has previously arranged a method of payment, and if the database does not indicate a previously arranged method of payment, automated diagnostic and treatment system **102** may prompt the patient to enter payment information, such as insurance, bank, or credit card information. Automated diagnostic and treatment system **102** may determine whether payment information is valid and automatically obtain an authorization from the insurance, EHR system, and/or the card issuer for payment for a certain amount for services rendered by the doctor. An invoice may be electronically presented to the patient, e.g., upon completion of a consultation, such that the patient can authorize payment of the invoice, e.g., via an electronic signature.

In embodiments, database **103** of patient's information (e.g., a secured cloud-based database) may comprise a security interface (not shown) that allows secure access to a patient database, for example, by using patient identification information to obtain the patient's medical history. The interface may utilize biometric, bar code, or other electronically security methods. In embodiments, medical instrument equipment **108** uses unique identifiers that are used as a control tool for measurement data. Database **103** may be a repository for any type of data created, modified, or received by diagnostic system **100**, such as generated diagnostic information, information received from patient's wearable electronic devices, remote video/audio data and instructions, e.g., instructions received from a remote location or from the application.

In embodiments, fields in the patient's electronic health care record (EHR) are automatically populated based on one or more of questions asked by diagnostic system **100**, measurements taken by the diagnostic system **100**, diagnosis and treatment codes generated by diagnostic system **100**, one or more trust scores, and imported patient health care data from one or more sources, such as an existing health care database. It is understood the format of imported patient health care data may be converted to be compatible with the EHR format of diagnostic system **100**. Conversely, exported patient health care data may be converted, e.g., to be compatible with an external EHR database.

In addition, patient-related data documented by diagnostic system **100** provide support for the code decision for the level of exam a doctor performs. Currently, for billing and reimbursement purposes, doctors have to choose one of any identified codes (e.g., ICD10 currently holds approximately 97,000 medical codes) to identify an illness and provide an additional code that identifies the level of physical exam/diagnosis performed on the patient (e.g., full body physical exam) based on an illness identified by the doctor.

In embodiments, patient answers are used to suggest to the doctor a level of exam that is supported by the identified illness, e.g., to ensure that the doctor does not perform unnecessary in-depth exams for minor illnesses or a treatment that may not be covered by the patient's insurance.

In embodiments, upon identifying a diagnostic system **100** generates one or more recommendations/suggestions/options for a particular treatment. In embodiments, one or more treatment plans are generated that the doctor may discuss with the patient and decide on a suitable treatment. For example, one treatment plan may be tailored purely for effectiveness, another one may consider the cost of drugs. In embodiments, diagnostic system **100** may generate a prescription or lab test request and consider factors, such as recent research results, available drugs and possible drug interactions, the patient's medical history, traits of the patient, family history, and any other factors that may affect treatment when providing treatment information. In embodiments, diagnosis and treatment databases may be continuously updated, e.g., by health care professionals, so that an optimal treatment may be administered to a particular patient, e.g., a patient identified as member of a certain risk group.

It is noted that sensors and measurement techniques may be advantageously combined to perform multiple functions using a reduced number of sensors. For example, an optical sensor may be used as a thermal sensor by utilizing IR technology to measure body temperature. It is further noted that some or all data collected by diagnostic system **100** may be processed and analyzed directly within automated diagnostic and treatment system **102** or transmitted to an external reading device (not shown in FIG. **1**) for further processing and analysis, e.g., to enable additional diagnostics.

FIG. **2** illustrates an exemplary patient diagnostic measurement system according to embodiments of the present disclosure. As depicted, patient diagnostic measurement system **200** comprises microcontroller **202**, spectrum imaging device, e.g., spectrum imaging device camera **204**, monitor **206**, patient-medical equipment activity tracking sensors, e.g., inertial sensor **208**, communications controller **210**, medical instruments **224**, identifiable marker, e.g., identifiable marker IR LED **226**, power management unit **230**, and battery **232**. Each component may be coupled directly or indirectly by electrical wiring, wirelessly, or optically to any other component in patient diagnostic measurement system **200**. Inertial sensor **208** may also be referred to as patient-equipment activity sensors inertial sensors **208** or simply sensors **208**.

Medical instrument **224** comprises one or more devices that are capable of measuring physical and non-physical characteristics of a patient that, in embodiments, may be customized, e.g., according to varying anatomies among patients, irregularities on a patient's skin, and the like. In embodiments, medical instrument **224** is a combination of diagnostic medical devices that generate diagnostic data based on patient characteristics. Exemplary diagnostic medical devices are heart rate sensors, otoscopes, digital stethoscopes, in-ear thermometers, blood oxygen sensors, high-definition cameras, spirometers, blood pressure meters, respiration sensors, skin resistance sensors, glucometers, ultrasound devices, electrocardiographic sensors, body fluid sample collectors, eye slit lamps, weight scales, and any devices known in the art that may aid in performing a medical diagnosis. In embodiments, patient characteristics and vital signs data may be received from and/or compared against wearable or implantable monitoring devices that gather sample data, e.g., a fitness device that monitors physical activity.

One or more medical instruments **224** may be removably attachable directly to a patient's body, e.g., torso, via patches or electrodes that may use adhesion to provide good physical or electrical contact. In embodiments, medical instruments **224**, e.g., a contact-less (or non-contact) thermometer, may perform contact-less measurements some distance away from the patient's body. Non-contact sensors my also support measurements for electrocardiograms (EKG) and electroencephalogram (EEG).

In embodiments, microcontroller **202** may be a secure microcontroller that securely communicates information in encrypted form to ensure privacy and the authenticity of measured data and activity sensor and patient-equipment proximity information and other information in patient diagnostic measurement system **200**. This may be accomplished by taking advantage of security features embedded in hardware of microcontroller **202** and/or software that enables security features during transit and storage of sensitive data. Each device in patient diagnostic measurement system **200** may have keys that handshake to perform authentication operations on a regular basis.

Spectrum imaging device camera **204** is any audio/video device that may capture patient images and sound at any frequency or image type. Monitor **206** is any screen or display device that may be coupled to camera, sensors and/or any part of patient diagnostic measurement system **200**. Patient-equipment activity tracking inertial sensor **208** is any single or multi-dimensional sensor, such as an accelerometer, a multi-axis gyroscope, pressure sensor, and a magnetometer capable of providing position, motion, pressure on medical equipment or orientation data based on patient interaction. Patient-equipment activity tracking inertial sensor **208** may be attached to (removably or permanently) or embedded into medical instrument **224**. Identifiable marker IR LED **226** represents any device, heat source, reflective material, proximity beacon, altimeter, etc., that may be used by microcontroller **202** as an identifiable marker like patient-equipment activity tracking inertial sensor **208**, identifiable marker IR LED **226** may be attachable to or embedded into medical instrument **224**.

In embodiments, communication controller **210** is a wireless communications controller attached either permanently or temporarily to medical instrument **224** or the patient's body to establish a bi-directional wireless communications link and transmit data, e.g., between sensors and microcontroller **202** using any wireless communication protocol known in the art, such as Bluetooth Low Energy, e.g., via an embedded antenna circuit that wirelessly communicates the data. One of ordinary skill in the art will appreciate that electromagnetic fields generated by such antenna circuit may be of any suitable type. In case of an RF field, the operating frequency may be located in the ISM frequency band, e.g., 13.56 MHz. In embodiments, data received by communications controller **210**, which may be a wireless controller, may be forwarded to a host device (not shown) that may run a software application.

In embodiments, power management unit **230** is coupled to microcontroller **202** to provide energy to, e.g., microcontroller **202** and communication controller **210**. Battery **232** may be a back-up battery for power management unit **230** or a battery in any one of the devices in patient diagnostic measurement system **200**. One of ordinary skill in the art will appreciate that one or more devices in patient diagnostic measurement system **200** may be operated from the same power source (e.g., battery **232**) and perform more than one function at the same or different times. A person of skill in the art will also appreciate that one or more components, e.g., sensors **208**, identifiable marker IR LED **226**, may be integrated on a single chip/system, and that additional electronics, such as filtering elements, etc., may be implemented to support the functions of medical instrument equipment measurement or usage monitoring and tracking in patient diagnostic measurement system **200** according to the objectives of the invention.

In operation, a patient may use medical instrument **224** to gather patient data based on physical and non-physical patient characteristics, e.g., vital signs data, images, sounds, and other information useful in the monitoring and diagnosis of a health-related condition. The patient data is processed by microcontroller **202** and may be stored in a database (not shown). In embodiments, the patient data may be used to establish baseline data for a patient health profile against which subsequent patient data may be compared.

In embodiments, patient data may be used to create, modify, or update EHR data. Gathered medical instrument equipment data, along with any other patient and sensor data, may be processed directly by patient diagnostic measurement system **200** or communicated to a remote location for analysis, e.g., to diagnose existing and expected health conditions to benefit from early detection and prevention of acute conditions or aid in the development of novel medical diagnostic methods.

In embodiments, medical instrument **224** is coupled to a number of sensors, such as patient-equipment tracking inertial sensor **208** and/or identifiable marker IR LED **226**, that may monitor a position/orientation of medical instrument **224** relative to the patient's body when a medical equipment measurement is taken. In embodiments, sensor data generated by sensor **208**, identifiable marker IR LED **226** or other sensors may be used in connection with, e.g., data generated by spectrum imaging device camera **204**, proximity sensors, transmitters, bolometers, or receivers to provide feedback to the patient to aid the patient in properly aligning medical instrument **224** relative to the patient's body part of interest when performing a diagnostic measurement. A person skilled in the art will appreciate that not all sensors **208**, identifiable marker IR LED **226**, beacon, pressure, altimeter, etc., need to operate at all times. Any number of sensors may be partially or completely disabled, e.g., to conserve energy.

In embodiments, the sensor emitter comprises a light signal emitted by IR LED **226** or any other identifiable marker that may be used as a reference signal. In embodiments, the reference signal may be used to identify a location, e.g., within an image and based on a characteristic that distinguishes the reference from other parts of the image. In embodiments, the reference signal is representative of a difference between the position of medical instrument **224** and a preferred location relative to a patient's body. In embodiments, spectrum imaging device camera **204** displays, e.g., via monitor **206**, the position of medical instrument **224** and the reference signal at the preferred location so as to allow the patient to determine the position of medical instrument **224** and adjust the position relative to the preferred location, displayed by spectrum imaging device camera **204**.

Spectrum imaging device camera **204**, proximity sensor, transmitter, receiver, bolometer, or any other suitable device may be used to locate or track the reference signal, e.g., within the image, relative to a body part of the patient. In embodiments, this augmented reality (AR) method may be accomplished by using an overlay method that overlays an image of a body part of the patient against an ideal model of device usage to enable real-time feedback for the patient. The reference signal along with signals from other sensors, e.g., patient-equipment activity inertial sensor **208**, may be used to identify a position, location, angle, orientation, or usage associated with medical instrument **224** to monitor and guide a patient's placement of medical instrument **224** at a target location and accurately activate a device for measurement. In other embodiments, methods of mixed reality, in which users wearing AR goggles may have virtual objects overlaid on real-world objects (e.g. a virtual clock on a real wall).

In embodiments, e.g., upon receipt of a request signal, microcontroller **202** activates one or more medical instruments **224** to perform measurements and sends data related to the measurement back to microcontroller **202**. The measured data and other data associated with a physical condition may be automatically recorded and a usage accuracy of medical instrument **224** may be monitored.

In embodiments, microcontroller **202** uses an image in any spectrum, motion signal and/or an orientation signal by patient-equipment activity inertial sensor **208** to compensate or correct the vital signs data output by medical instrument **224**. Data compensation or correction may comprise filtering out certain data as likely being corrupted by parasitic effects and erroneous readings that result from medical instrument **224** being exposed to unwanted movements caused by perturbations or, e.g., the effect of movements of the patient's target measurement body part.

In embodiments, signals from two or more medical instruments **224**, or from medical instrument **224** and patient-activity activity system inertial sensor **208**, are combined, for example, to reduce signal latency and increase correlation between signals to further improve the ability of patient diagnostic measurement system **200** to reject motion artifacts to remove false readings and, therefore, enable a more accurate interpretation of the measured vital signs data.

In embodiments, spectrum imaging device camera **204** displays actual or simulated images and videos of the patient and medical instrument **224** to assist the patient in locating a desired position for medical instrument **224** when performing the measurement so as to increase measurement accuracy. Spectrum imaging device camera **204** may use image or facial recognition software to identify and display eyes, mouth, nose, ears, torso, or any other part of the patient's body as reference.

In embodiments, patient diagnostic measurement system **200** uses machine vision software that analyzes measured image data and compares image features to features in a database, e.g., to detect an incomplete image for a target body part, to monitor the accuracy of a measurement and determine a corresponding score. In embodiments, if the score falls below a certain threshold, patient diagnostic measurement system **200** may provide detailed guidance for improving measurement accuracy or to receive a more complete image, e.g., by providing instructions on how to change an angle or depth of an otoscope relative to the patient's ear.

In embodiments, the machine vision software may use an overlay method to mimic a patient's posture/movements to provide detailed and interactive instructions, e.g., by displaying a character, image of the patient, graphic, or avatar on monitor **206** to provide feedback to the patient. The instructions, image, or avatar may start or stop and decide what help instruction to display based on the type of medical instrument **224**, the data from spectrum imaging device camera **204**, patient-equipment activity sensors inertial sensors **208**, bolometer, transmitter and receiver, and/or identifiable marker IR LED **226** (an image, a measured position or angle, etc.), and a comparison of the data to idealized data. This further aids the patient in correctly positioning and operating medical instrument **224** relative to the patient's body, ensures a high level of accuracy when operating medical instrument **224**, and solves potential issues that the patient may encounter when using medical instrument **224**.

In embodiments, instructions may be provided via monitor **206** and describe in audio/visual format and in any desired level of detail, how to use medical instrument **224** to perform a diagnostic test or measurement, e.g., how to take temperature, so as to enable patients to perform measurements of clinical-grade accuracy. In embodiments, each sensor **208**, identifiable marker IR LED **226**, e.g., proximity, bolometer, transmitter/receiver may be associated with a device usage accuracy score. A device usage accuracy score generator (not shown), which may be implemented in microcontroller **202**, may use the sensor data to generate a medical instrument usage accuracy score that is representative of the reliability of medical instrument **224** measurement on the patient. In embodiments, the score may be based on a difference between an actual position of medical instrument **224** and a preferred position. In addition, the score may be based on detecting a motion, e.g., during a measurement. In embodiments, the device usage accuracy score is derived from an error vector generated for one or more sensors **208**, identifiable marker IR LED **226**, deep learning system **105**. In embodiments, the device usage accuracy score is derived from an error vector generated for one or more sensors **208**, identifiable marker IR LED **226**. The resulting device usage accuracy score may be used when generating or evaluating medical diagnosis data.

In embodiments, microcontroller **202** analyzes the patient measured medical instrument data to generate a trust score indicative of the acceptable range of the medical instrument. For example, by comparing the medical instrument measurement data against reference measurement data or reference measurement data that would be expected from medical instrument **224**. As with device usage accuracy score, the trust score may be used when generating or evaluating a medical diagnosis data.

FIG. **3**A illustrates an exemplary system **300** for measuring a patient's body parts utilizing optical medical instruments and deep learning systems according to embodiments of the present disclosure. System **300** may comprise automated diagnostic and treatment system **102**, deep learning system **105**, doctor interface station **104** and patient kiosk **301**. Patient kiosk **301** may comprise patient interface station **106**, kiosk cameras including sensors/camera-**1** **303**, sensors/camera-**2** **304** and instrument **312**. As illustrated, patient **310** is present in patient kiosk **301**. Kiosk cameras may also be referred to as camera modules. Instrument **312** may be, but not limited to, an otoscope. Deep learning system **105** may be, but not limited to, a deep convolution neural network (DCNN).

An objective of system **300** includes the accurate acquisition of medical measurement data of a target spot of a body part of patient **310**. To assist in acquiring accurate medical measurement data, the automated diagnostic and treatment system **102** provides instructions to patient **310** to allow patient **310** to precisely position instrument **312** in proximity to a target spot of a body part of patient **310**. That is, the movement of instrument **312** may be controlled by the patient **310**. Based on a series of images acquired from the kiosk cameras and instrument **312**, these instructions may be generated. Subsequent images from instrument **312** are analyzed by automated diagnostic and treatment system **102** utilizing database **103** and deep learning system **105** to obtain measured medical data. The accuracy of the instrument **312** positioning and the medical measured data may be determined by automated diagnostic and treatment system **102**, and deep learning system **105** via an error threshold measurement. When accurately positioned, quality medical measurements are generated for the target spot of a body part of patient **310**. As illustrated in FIG. **3**A, patient **310** has positioned instrument **312**, which may be an otoscope, in proximity to the ear of patient **310**. In other embodiments, instrument **312** may be positioned in proximity to another body part. In other embodiments, patient **310** may be fitted with haptic/tactile feedback sensors which may augment the patient guidance instructions for taking measurements. As an example, during an ear exam, should the patient need to point the otoscope left, haptic feedback in the form of a buzzer/vibrator could be elicited on the side of the device in which movement is required (i.e. left side). These haptic feedback devices may include, but are not limited to, vibration motors (similar to those found in smart phones) fitted around the medical instrument equipment to give tactile instructions (e.g. vibration on the left side of the medical device to instruct the patient to move the medical device left), or flywheels to give kinesthetic feedback such as resisting movement in undesirable directions, and aiding movement in the correct direction (similar to certain virtual reality peripherals). Instrument **312** may be wirelessly coupled to patient interface station **106**.

The automated diagnostic and treatment system **102**, deep learning system **105**, doctor interface station **104** and patient interface station **106** are operable as previously described herein relative to FIG. **1**. The automated diagnostic and treatment system **102** may send a command to the patient interface station **106** requesting sensors/camera-**1** **303** and sensors/camera-**2** **304** to capture images of patient **310** and instrument **312**. The captured images (sometimes called "posed" images) may be analyzed by the deep learning system **105** to determine the position of instrument **312** relative to the body part, which may include the location of instrument **312** to the body part, the angle of instrument **312** to the body part, and the rotation of instrument **312** to the body part. From this positioning analysis, the automated diagnostic and treatment system **102** may provide an initial set of instructions to patient **310** to assist patient **310** to position instrument **312** in proximity to the target spot of the body part. As an example, the first set of instructions may request the patient to position the instrument **312** adjacent to the patient's right ear. After patient **310** acts on the first set of instructions, the automated diagnostic and treatment system **102** captures a second set of images and determines if instrument **312** is within a pose threshold of the target spot of the body part. The pose threshold may be less than one inch. These instructions may be considered a "coarse" set of instructions, or "coarse tuning", inasmuch as the estimates are based on images obtained by sensors/camera-**1** **303** and sensors/camera-**2** **304** that have a distance d1 between the camera and the instrument **312**. Distance d1 may be several feet.

As illustrated in patient kiosk **301**, there are two camera/sensor modules. In some embodiments, there may be N camera/sensor modules, where N is equal to one of more camera/sensor modules.

Instrument **312** may comprise a camera that may be located on one end of instrument **312**. Automated diagnostic and treatment system **102** may command, via patient interface station **106**, instrument **312** to capture images of a target spot of the body part. Inasmuch as instrument **312** is in close proximity to the body part, these captures images provide detailed information on the position of instrument **312** relative to the body part. The images from instrument **312** are analyzed, resulting in another set of instruction for patient **310** for the positioning of instrument **312** relative to the target spot of the body part. Based on the another set of instructions, patient **310** may position instrument **312** more accurately relative to the target spot of the body part of patient **310**. The another set of instructions may have refined, i.e., "fine tuned", the initial set of instructions because the another set of instructions is based on images captured where the instrument camera is distance d2 from the body part. Distance d2 may be less than 1 inch.

This process may be repeated as newly captured images by instrument **312** are analyzed by the automated diagnostic and treatment system **102** to determine the updated positions of instrument **312** relative to the body part. The updated positions may include the location of instrument **312** to the body part, the angle of instrument **312** to the body part, and the rotation of instrument **312** to the body part. From this positioning analysis, the automated diagnostic and treatment system **102** provides yet another set of instructions to patient **310** to assist patient **310** to position instrument **312** in proximity to the target spot of the body part. This yet another of instructions may further refine the initial sets of instructions. The instructions may be communicated to patient **310** via a visual display or via haptic/tactile feedback sensors.

The instructions may be refined by the automated diagnostic and treatment system **102** analyzing the images from the instrument camera and the images from the kiosk cameras by utilizing deep learning system **105** and database **103** to obtain updated estimates of 1) the position of instrument **312** relative to the target spot of the body part and 2) measured body parts. When automated diagnostic and treatment system **102** achieves an error threshold to ensure measurement accuracy, the medical measurement data is provided to a physician by the automated diagnostic and treatment system **102** via the doctor interface station **104**.

FIG. **3**B illustrates another exemplary system **320** for measuring a patient's body parts or a medical instrument (not shown) utilizing cameras and sensors according to embodiments of the present disclosure. System **320** is based on the principle of determine the time-of-flight (TOF) for each emitted pulse of light. Light detection and ranging systems, such as camera/sensors **322**, may employ pulses of light to measure distance to an object based on the time of flight (TOF) of each pulse of light. A pulse of light emitted from a light source of a light detection and ranging system interacts with a distal object. A portion of the light reflects from the object and returns to a detector of the light detection and ranging system. Based on the time elapsed between emission of the pulse of light and detection of the returned pulse of light, the distance to the object may be estimated.

The light pulse may hit multiple objects, each having a different distance from the laser, causing multi-return signals to be received by the light detection and ranging system detector. Multi-return signals may provide more information of the environment to improve mapping or reconstruction. A dedicated detector may be required to precisely identify each return with its associated time delay information. The resulting images may be referred to as “pose images”. In other words, one or more camera modules may provide a pose estimate based on time of flight of multiple light signals emitted from each of the one or more camera modules and reflected back to the one or more camera modules.

As illustrated in FIG. **3**B, camera/sensors **322** may emits signals S**1**, S**2** and S**3**. These signals may reflect off patient **330** or off a fixed surface, such as a wall or floor. In the kiosk, the walls and floor may have identifiers that can assist in the image identification of the body part of patient **330**. The reflection of signals S**1**, S**2** and S**3** may be detected by camera/sensors **322** and communicated to a diagnostic system, such as automated diagnostic and treatment system **102**. Automated diagnostic and treatment system **102** can determine the distances associated with signals S**1**, S**2** and S**3** based on the TOF of each signal. This process may result in a pose estimate, which may be viewed as a pose image. Identifier **324** may assist in identifying a position of a patient's body parts or a medical instrument.

FIG. **4**A illustrates an exemplary method **400** of measuring a patient's body part utilizing an optical medical instrument according to embodiments of the present disclosure. As illustrated, instrument **402** may be positioned in an ear of patient **404**. As previously discussed relative to FIG. **3**A, the patient **404** can receive instructions from a diagnostic system to improve the accuracy of the position of instrument **402** relative to a target spot of a body part of patient **404**.

FIG. **4**B illustrates an exemplary optical medical instrument **420** according to embodiments of the present disclosure. Optical medical instrument **420** may comprise instrument **422**, which may comprise instrument camera **424**, identifiable marker **428** and wireless device **426**. Instrument **422** may also include a serial number on its body. Instrument **422** may be easily held and positioned by a user, such as patient **310** of FIG. **3**A. Although instrument **422** includes wireless device **426**, in other embodiments, instrument **422** may be coupled to a diagnostic system via a wired or optical technology. Also, although instrument **422** illustrates instrument camera **424** is located on a tip or one end of instrument **422**, in other embodiments, instrument camera **424** may be located in another location on instrument **422**. When a kiosk camera/sensor endeavors to determine an angle or rotation of instrument **422** relative to a body party of a patient, identifiable marker **428** or the serial number may assist in determining these measurements. In some embodiments, identifiable marker **428** may be an image of a ring of flowers and may comprise reflective material. Instrument **402** and instrument **422** may be otoscopes.

FIG. **4**C illustrates an exemplary optical medical instrument **440** being positioned at an angle, position and rotation according to embodiments of the present disclosure.

FIG. **5**A and FIG. **5**B are flowcharts **500** and **540** depicting illustrative methods for making accurate medical patient measurements, according to embodiments of the present disclosure. The methods comprise the steps of:

Receiving a first set of pose images, by a diagnostic system, of an instrument in close proximity of a body part of a patient, wherein pose images are generated by one or more kiosk cameras. (step **502**)

Analyzing the first set of pose images by the diagnostic system utilizing a deep learning system, to obtain (1) a first set of estimates of position of the instrument relative to the body part (initial pose estimates) and (2) first set of body part measurements. (step **504**)

Providing a first set of instructions, by the diagnostic system, based on the first set of estimates, to the patient to adjust the position of the instrument relative to a target spot of the body part. This set of instructions may direct the patient to position the instrument at a particular ear. (step **506**)

Receiving a second/another set of pose images, by the diagnostic system, after the patient has adjusted the position of the instrument relative to the target spot of the body part based on the first set of instructions. (step **508**)

Analyzing the second/another set of pose images, by the diagnostic system utilizing deep learning system, to obtain (1) a second/another set of estimates of the position of the instrument relative to the target spot of the body part and (2) second/another set of body part measurements. (step **510**) Steps **502**, **504**, **506**, **508** and **510** define a coarse tuning method based on pose images.

Determining whether the instrument is within a pose threshold of a target spot of the body part. (step **512**) The diagnostic system makes this determination.

If the pose threshold is achieved, proceed with fine tuning at step **515**.

If the pose threshold is not achieved, providing another set of instructions based on the second/another set of estimates to the patient to further adjust the position of the instrument relative to the target spot of the body part. The another set of instructions may cause the patient to re-adjust the instrument position relative to the target spot of the body. (step **513**) Then repeat steps **508**, **510**, and **512**.

Receiving a set of instrument images, by the diagnostic system, of the target spot of the body part, wherein the set of instrument images are generated by the instrument camera located on one end of the instrument. (step **515**)

Analyzing, by the diagnostic system, the set/another set of instrument images from the instrument camera and prior sets of pose images from the kiosk cameras utilizing a deep learning system to obtain (1) a third/another set of estimates of the position of the instrument relative to the target spot of the body part and (2) a third/another set of body part measurements (step **516**) Steps **515** and **516** define a fine tuning method. A deep learning system, may be, but without limitation, deep convolution neural network (DCNN).

Determining whether an error threshold to ensure measurement accuracy for the instrument positioning relative to the target spot of the body part of the patient has been achieved. (step **518**) The deep learning system makes this determination.

If the error threshold is achieved, providing medical measured data for the target spot of the body part to a physician and to a deep learning system database. (step **522**)

If the error threshold is not achieved, providing another set of instructions, based on the third/another set of estimates, to the patient to further adjust the position of the instrument relative to the target spot of the body part. (step **519**)

Receiving another set of instrument images, by the diagnostic system, of the target spot of the body part, after the patient has adjusted the position of the instrument relative to the body part based on the another set of instructions. (step **520**)

Repeating the analysis of the another set of images from the instrument camera, i.e., step **516** and subsequent steps.

FIG. **5**C is comprises flowchart **560** of an illustrative method for making accurate medical otoscope patient measurements, according to embodiments of the present disclosure. The method comprise the steps of:

Providing, by a diagnostic system, instructions to the patient to adjust the position of an otoscope relative to a selected ear of the patient based on a first set of images (pose images) from one or more kiosk cameras, and confirming the otoscope is within a pose threshold of the selected ear. A deep learning system may be utilized in this step. (step **562**)

Receiving a second set of images, by the diagnostic system, of the selected ear, the second set of images generated by an otoscope camera located on one end of the otoscope. (step **563**)

Analyzing the first (or additional) set of images from one or more kiosk cameras, a second (or additional) set of images from the otoscope and utilizing a deep learning system to obtain estimates of the position of the otoscope relative to the selected ear and body measurements. The deep learning system may be, but not limited to, a deep convolution neural network (step **564**)

Determining whether an error threshold to ensure measurement accuracy for the otoscope positioning relative to the selected ear of the patient has been achieved? (step **566**) The deep learning system makes this determination.

If the error threshold is achieved, providing medical measured data for the selected ear to a physician and to a deep learning database. (step **570**)

If the error threshold is not achieved, receiving additional images from the otoscope based on additional positioning instructions and optionally additional images from the kiosk cameras, then repeating steps **564** and **566**. (step **568**)

In embodiments, a time maybe calculated at which the selected treatment is expected to show a result and patient feedback may be requested, e.g., as part of a feedback process, to improve diagnosis and treatment reliability. In embodiments, the selected treatment and/or the patient feedback may be used to adjusting one or more of the metrics. For example, based on one or more of the metrics a series of treatment plans maybe generated by using an algorithm that combines the metrics. In embodiments, calculating the selected treatment comprises using cost as a factor.

One skilled in the art will recognize that: (1) certain steps may optionally be performed; (2) steps may not be limited to the specific order set forth herein; and (3) certain steps may be performed in different orders; and (4) certain steps may be done concurrently.

In embodiments, one or more computing systems, such as mobile/tablet/computer or the automated diagnostic system, may be configured to perform one or more of the methods, functions, and/or operations presented herein. Systems that implement at least one or more of the methods, functions, and/or operations described herein may comprise an application or applications operating on at least one computing system. The computing system may comprise one or more computers and one or more databases. The computer system may be a single system, a distributed system, a cloud-based computer system, or a combination thereof.

It shall be noted that the present disclosure may be implemented in any instruction-execution/computing device or system capable of processing data, including, without limitation phones, laptop computers, desktop computers, and servers. The present disclosure may also be implemented into other computing devices and systems. Furthermore, aspects of the present disclosure may be implemented in a wide variety of ways including software (including firmware), hardware, or combinations thereof. For example, the functions to practice various aspects of the present disclosure may be performed by components that are implemented in a wide variety of ways including discrete logic components, one or more application specific integrated circuits (ASICs), and/or program-controlled processors. It shall be noted that the manner in which these items are implemented is not critical to the present disclosure.

Having described the details of the disclosure, an exemplary system that may be used to implement one or more aspects of the present disclosure is described next with reference to FIG. **6**. Each of patient interface station **106** and automated diagnostic and treatment system **102** in FIG. **1** may comprise one or more components in the system **600**. As illustrated in FIG. **6**, system **600** includes a central processing unit (CPU) **601** that provides computing resources and controls the computer. CPU **601** may be implemented with a microprocessor or the like, and may also include a graphics processor and/or a floating point coprocessor for mathematical computations. System **600** may also include a system memory **602**, which may be in the form of random-access memory (RAM) and read-only memory (ROM).

A number of controllers and peripheral devices may also be provided, as shown in FIG. **6**. An input controller **603** represents an interface to various input device(s) **604**, such as a keyboard, mouse, or stylus. There may also be a scanner controller **605**, which communicates with a scanner **606**. System **600** may also include a storage controller **607** for interfacing with one or more storage devices **608** each of which includes a storage medium such as magnetic tape or disk, or an optical medium that might be used to record programs of instructions for operating systems, utilities and applications which may include embodiments of programs that implement various aspects of the present disclosure. Storage device(s) **608** may also be used to store processed data or data to be processed in accordance with the disclosure. System **600** may also include a display controller **609** for providing an interface to a display device **611**, which may be a cathode ray tube (CRT), a thin film transistor (TFT) display, or other type of display. System **600** may also include a printer controller **612** for communicating with a printer **613**. A communications controller **614** may interface with one or more communication devices **615**, which enables system **600** to connect to remote devices through any of a variety of networks including the Internet, an Ethernet cloud, an FCoE/DCB cloud, a local area network (LAN), a wide area network (WAN), a storage area network (SAN) or through any suitable electromagnetic carrier signals including infrared signals.

In the illustrated system, all major system components may connect to a bus **616**, which may represent more than one physical bus. However, various system components may or may not be in physical proximity to one another. For example, input data and/or output data may be remotely transmitted from one physical location to another. In addition, programs that implement various aspects of this disclosure may be accessed from a remote location (e.g., a server) over a network. Such data and/or programs may be conveyed through any of a variety of machine-readable medium including, but are not limited to: magnetic media such as hard disks, floppy disks, and magnetic tape; optical media such as CD-ROMs and holographic devices; magneto-optical media; and hardware devices that are specially configured to store or to store and execute program code, such as application specific integrated circuits (ASICs), programmable logic devices (PLDs), flash memory devices, and ROM and RAM devices.

Embodiments of the present disclosure may be encoded upon one or more non-transitory computer-readable media with instructions for one or more processors or processing units to cause steps to be performed. It shall be noted that the one or more non-transitory computer-readable media shall include volatile and non-volatile memory. It shall be noted that alternative implementations are possible, including a hardware implementation or a software/hardware implementation. Hardware-implemented functions may be realized using ASIC(s), programmable arrays, digital signal processing circuitry, or the like. Accordingly, the "means" terms in any claims are intended to cover both software and hardware implementations. Similarly, the term "computer-readable medium or media" as used herein includes software and/or hardware having a program of instructions embodied thereon, or a combination thereof. With these implementation alternatives in mind, it is to be understood that the figures and accompanying description provide the functional information one skilled in the art would require to write program code (i.e., software) and/or to fabricate circuits (i.e., hardware) to perform the processing required.

It shall be noted that embodiments of the present disclosure may further relate to computer products with a non-transitory, tangible computer-readable medium that have computer code thereon for performing various computer-implemented operations. The media and computer code may be those specially designed and constructed for the purposes of the present disclosure, or they may be of the kind known or available to those having skill in the relevant arts. Examples of tangible computer-readable media include, but are not limited to: magnetic media such as hard disks, floppy disks, and magnetic tape; optical media such as CD-ROMs and holographic devices; magneto-optical media; and hardware devices that are specially configured to store or to store and execute program code, such as application specific integrated circuits (ASICs), programmable logic devices (PLDs), flash memory devices, and ROM and RAM devices. Examples of computer code include machine code, such as produced by a compiler, and files containing higher level code that are executed by a computer using an interpreter. Embodiments of the present disclosure may be implemented in whole or in part as machine-executable instructions that may be in program modules that are executed by a processing device. Examples of program modules include libraries, programs, routines, objects, components, and data structures. In distributed computing environments, program modules may be physically located in settings that are local, remote, or both.

For purposes of this disclosure, an information handling system may include any instrumentality or aggregate of instrumentalities operable to compute, calculate, determine, classify, process, transmit, receive, retrieve, originate, switch, store, display, communicate, manifest, detect, record, reproduce, handle, or utilize any form of information, intelligence, or data for business, scientific, control, or other purposes. For example, an information handling system may be a personal computer (e.g., desktop or laptop), tablet computer, mobile device (e.g., personal digital assistant (PDA) or smart phone), server (e.g., blade server or rack server), a network storage device, or any other suitable device and may vary in size, shape, performance, functionality, and price. The information handling system may include random access memory (RAM), one or more processing resources such as a central processing unit (CPU) or hardware or software control logic, ROM, and/or other types of nonvolatile memory. Additional components of the information handling system may include one or more disk drives, one or more network ports for communicating with external devices as well as various input and output (I/O) devices, such as a keyboard, a mouse, touchscreen and/or a video display. The information handling system may also include one or more buses operable to transmit communications between the various hardware components.

One skilled in the art will recognize no computing system or programming language is critical to the practice of the present disclosure. One skilled in the art will also recognize that a number of the elements described above may be physically and/or functionally separated into sub-modules or combined together.

It will be appreciated to those skilled in the art that the preceding examples and embodiment are exemplary and not limiting to the scope of the present disclosure. It is intended that all permutations, enhancements, equivalents, combinations, and improvements thereto that are apparent to those skilled in the art upon a reading of the specification and a study of the drawings are included within the true spirit and scope of the present disclosure.

What is claimed is:

1. A system comprising:

an automated diagnostic system comprising a database;

a deep learning system coupled to the automated diagnostic system;

one or more camera modules operable to send images of an instrument, which is in proximity to a body part of a patient, to the automated diagnostic system; and

the instrument comprising an instrument camera and operable to send images of the body part of the patient to the automated diagnostic system, wherein the patient controls instrument's movement, wherein, the automated diagnostic system, utilizing the images from the one or more camera modules, the images from the instrument camera and the deep learning system, provide visual instructions to the patient to adjust the instrument from a first position to a second position proximately closer to a target spot of the body part of the patient.

2. The system according to claim **1**, further comprising: a patient interface station operable to send and receive information from the automated diagnostic system, the one or more camera modules and the instrument.

3. The system according to claim **1**, wherein the automated diagnostic system is operable to analyze information provided by the one or more camera modules, the instrument and the deep learning system to generate medical measured data of the body part of the patient.

4. The system according to claim **3**, wherein the medical measured data of the body part of the patient is communicated to a physician and a deep learning database.

5. The system according to claim **1**, wherein the one or more camera modules provide a pose estimate based on time of flight of multiple light signals emitted from each of the one or more camera modules and reflected back to the one or more camera modules.

6. The system according to claim **1**, wherein the one or more camera modules determine a location, an angle and a rotation of the instrument relative to the body part of the patient.

7. The system according to claim **6**, wherein the one or more camera modules determine the rotation of the instrument relative to the body part of the patient based on an identifiable marker on the instrument, wherein the identifiable marker comprises an image and/or a serial number.

8. The system according to claim **7**, wherein other instructions may be communicated to the patient via haptic feedback sensors.

9. The system according to claim **1**, wherein the instrument is an opthalmoscope, intraoral camera, auriscope, or otoscope.

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